TROPICAL AGRICULTURE

THE OFFICIAL JOURNAL OF THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE

VOL. XXIV, NOS. 4–6 APRIL–JUNE, 1947 PRICE 1/6d.

CONTENTS

	PAGE
Development of Natural Resources	37
Maize Seed Storage	40
Effective Rainfall and Soil Moisture in Trinidad	45
Longevity of Bamboo Seed under different Storage Conditions	51
Eradication of Mosquitoes and Tsetse Flies ...	53
Coffee Planting in South India	54
Cacao Diseases in Brazil	56
Control of Piano Grass	57
Pests and Diseases of Cacao in Trinidad ...	60
Peasant Agriculture in the Leeward and Windward Islands	61
Research at the Institute of Tropical Agriculture, Puerto Rico	71
Deterioration of Cane in a Storage Pile ...	72

THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE, TRINIDAD, B.W.I.

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DEVELOPMENT OF NATURAL RESOURCES*

Productive land is unlike any other natural resource. It is characterised by the element of life placed by Nature in the thin mantle of fruitful soil occurring over a limited portion of the earth's surface. It is this life-producing quality that makes some lands productive, and it is the absence of this quality that makes some barren.

Productive land is further differentiated from other natural resources in that it must be maintained and used simultaneously; that is, it must be kept intact while in use. All other natural resources, with very few exceptions, must be taken from the earth—separated from it—in order to be used by man. The exceptions are certain forms of wild life and those natural areas which, because of their aesthetic values, are kept in their original state.

Productive land is much more limited than commonly has been supposed. It occurs only on the surface of the earth, and only on part of this surface. It is not permanent. Once the fertile topsoil is washed or blown away, it cannot be restored or replaced in any practical way for generations. And what is left—subsoil—usually is far less productive, or sterile, and less stable. There are no undiscovered reserves of productive land of any substantial area. We cannot dig deeper into the earth and find new productive soil. We cannot pump it from wells, plant it with seeds, or dig it from mines. We must keep what we have or do without. Assorted residues of sand and gravel left stranded along streamways are of small value.

Productive land is the only natural resource without which we cannot live. We are completely dependent on it for the food we eat, except fish. We also depend on it for a very large share of our clothing and shelter. We cannot get enough to feed ourselves or provide our clothing from the oceans. On any large scale, hydroponics would be utterly impractical. We might conceivably turn sometime to some form of synthetic food, as pills, plus a roughage, but this appears to be a fantastic extreme, still far away, and likely, if it ever comes, it will be decidedly unpopular.

There is no doubt about the need for protecting productive land. Year after year, for generations, man has been steadily engaged in ruining millions and millions of acres of this basic resource. Every

* Abridged from an article by H. H. Bennett, Chief, Soil Conservation Service, U.S. Department of Agriculture, Washington, D.C. which was published in *Science*, 105, No. 2714, 1947.

hard rain falling on unprotected, cultivated, or overgrazed sloping land washes additional tons of soil downslope, downstream, into the rivers, reservoirs, and oceans. There is no practical way of bringing this back. And every hard wind, blowing across bare, dry soil, whether sloping or level, adds to the damage. Wind lifts the fine soil particles into the air and often develops huge dust storms that destructively scatter the substance of the land. What is left behind frequently, is infertile, shifting sand that smothers out vegetation on neighbouring good land.

When the world was younger and our population much smaller, we could, perhaps, stand such waste, but that time is past. It is not defeatism to say that the world is fast maturing and must assume now a mature responsibility for its resources. It is not limiting the horizons of the future to say that land exploitation must stop. It is simply a matter of commonsense and self-preservation. Besides saving soil and water—the two go together—soil conservation results in increased yields per acre. It is also easier and cheaper to farm on the contour than up and down hill.

To-day, throughout our world, there are left only about 4,000,000,000 acres of immediately arable land, the productivity of a great deal of which is only fair to medium. Some of it is poor. Yet we must count on all of it to feed a population reported to be in excess of 2,000,000,000, and still increasing.

The United States is somewhat better off, from the standpoint of productive land, than most nations. Although it has ruined more good land in less time than any other nation recorded in history, it had an unprecedented supply to begin with. There is little margin left now but there is still enough productive land if it is taken care of. The present standard of living cannot be maintained if much more is lost. If the losses should continue the Nation would suffer even more seriously. Records show that for further practical cultivation about one-fifth of the original area of tillable land was ruined. A third of what remains has already been badly damaged, another third is highly valuable and the erosion process is still going on.

How did this come about? There are several reasons but probably the following are the main ones. First, we began losing land to erosion when the world was still young. People came to regard land as limitless and inexhaustible. Second, the apparent abundance of good land for so many generations gave rise to a careless and prodigal attitude. Third, in modern times, the leaders of thought and nations too often have had no personal knowledge or understanding of the land. Further, too much of the land traditionally has been in the hands of the untutored and inept: the most precious natural resource on earth in too many places has habitually been in charge of those who have had no greater qualifications for the trusteeship than the coincidence of inheritance or birth on the land. Fifth, too few farms have produced surplus capital for the owner over a period of years. Sixth, our agricultural scientists failed completely, over bygone years, to recognise land for what it is—an impermanent and complex resource. They considered soil permanent and synonymous with land. As a result of this mistake, both agriculture and the land suffered. Soil is but one part of land. For all practical purposes, land must be regarded in terms of all its component parts of soil, slope, climate, and susceptibility to erosion. The early scientists largely ignored erosion, paid little attention to slope, called the weather inevitable, and took soil samples right and left. In the main, however, agricultural science was not greatly concerned about the land. In large degree it was more interested in the health and breeding of livestock; improvement in strains of grasses, legumes, grains, and fibres; and modernisation of machinery and equipment. All of this was beneficial, but it did neglect the capital stock of agriculture and the source of production—the land itself. Seventh, in agriculture as in other enterprises we often wait until we are sick before we call the doctor. There is an element of human nature about this, and it has operated on the land. We did not practise preventive medicine, and now we must try to cure a malady—erosion—that has gotten into our system and weakened us.

So much for history. There is little to be gained by a review of past shortcomings except that it will help us avoid similar pitfalls in the future. To-day we are profiting from the lessons of the past. We know now:

(1) That productive land is neither limitless nor inexhaustible. On the contrary, we have learned that the area of productive land is steadily shrinking before the onslaught of erosion.

(2) That land must be expertly cared for if it is to be maintained in a productive state.

(3) That productive land must assume an ever more prominent position in the thinking of the people and their leaders. As the source of food for all people, rural and urban, it must have the regular intelligent consideration that such indispensable wealth merits.

(4) That, since society as a whole, depends absolutely on the produce of the land for its present and future existence, society as a whole must share in the responsibility and cost of maintaining land in a productive state. The individual land owner or operator has neither the resources nor the ability to carry the burden alone, and he has control only for a lifetime.

(5) That science must inevitably devote an increasing share of its attention to the problems of maintaining the substance and improving the yield of productive land.

(6) That action is imperative. Time is running out between the impeding pincers of an increasing population and a dwindling area of productive land.

(7) That the technological key to future consideration of land development is scientific analysis of each parcel of land of any important extent to determine: (a) the type of production for which it is best suited physically and economically, as between row crops, forage, trees, grain, or wildlife; and (b) the conservation measures, such as terracing, strip cropping, and contouring, necessary to maintain it in a permanently productive state under maximum use.

(8) That practical treatment must be based on this analysis—the character of the land and its needs.

Lands vary widely from place to place and even on the same farm or field. Every variation in the combination of soil, slope, climate, and susceptibility to erosion means a variation in the use and treatment necessary to keep the land permanently productive. Thus, engineering measures are used to supplement agronomic and fertility measures wherever necessary, and *vice versa,* according to need, adaptability, and economic limitations.

This is the basic principle underlying the new land technology developed in the United States during the past 14 years by the Soil Conservation Service (first called Soil Erosion Service). It is being applied to an ever-increasing area of land by American farmers, acting with the assistance of Service technicians. By the middle of 1947 more than 100,000,000 acres in all parts of the United States will be farmed in this modern conservation way; that is, each of the 100,000,000 acres or more will be used according to its individual capabilities and will be treated according to its conservation needs.

In the United States, land technology is spreading through a new democratic device known as the soil conservation district. The district is a sub-division of State government, brought into being by a process of referendum among the land-owners and operators involved. In practical application it is a legal organisation of land-owners and operators within a designated area for the purpose of developing and carrying forward a mutually desirable programme of soil conservation. Its principal advantages are in the encouragement of local initiative and in the greater strength that comes with organised numbers—farmers and ranchers working together.

In soil conservation districts the farmers themselves decide what they want to do to improve their land and water resources and how they want to go about doing it. Then they proceed along this course, working together, and utilising all the available facilities and services they can command. In almost every instance, districts are obtaining technical guidance from the Soil Conservatiion Service.

Although democratic soil conservation districts are being employed in the United States to further the application of land technology, other nations may choose to utilize other means. A number, however, including the Union of South Africa, Mexico, and parts of Australia, have adopted the soil conservation district method.

In the long run, the overwhelming urge of mankind for survival will dictate that every remaining productive acre be handled in such a way that it will continue to produce indefinitely. In the meantime, other factors are combining to speed up the application of technology to the land. From the standpoint of the individual and the nation alike, the development and application of soil and water conservation technology (the tool of soil conservation science) is good business. It results in greater yields and greater returns per acre for the capital and labour expended. Moreover, it maintains or improves the basic strength and self-sufficiency of individual and nation. It probably can prevent at least half of potential famines of the future.

By increasing the per-acre, per-farm, and per-nation supply of food and fibre, conservation technology can provide the basis for an improved standard of living and simultaneously reduce the hunger and discontent among peoples which so frequently leads to discord, dictatorships, and war.

For these and other reasons, the application of land technology is certain to spread around the world, either voluntarily or by decree. By the year 1996 this world journey probably will be well advanced. By that year or before, it will have accomplished changes in agriculture tantamount to a beneficial revolution on the land.

Almost certainly, productive land will have become a major factor in national and international deliberations. In all probability there would have been better international relationships if we had worked together more on ways and means of keeping land productive.

Production in the agricultural areas of the world will be more diversified; there will be pronounced increases in the acreages devoted to livestock and trees.

Agricultural production will be restored or improved in millions of communities throughout the world, solving in large measure some of the most difficult problems of food distribution and human nutrition now confronting mankind.

The nutritive value of food produced on land rich in the constituents of plant nutrition undoubtedly will be greater than that from impoverished land, which has been stripped of its topsoil by erosion, with everything the topsoil contains: available elements of nutrition, both minor and major, all that man puts into the topsoil, and everything else. With so much eroded land around the earth, is there any wonder that malnutrition and famine are so widespread?

Development of land and water resources for agriculture, as by drainage or irrigation, will be governed primarily by factual, technological elements of land use and land maintenance rather than by promotional, exploitive, or political standards.

Also, people will learn that it is easier on machine, horse, and man to farm according to conservation standards than to follow haphazard methods not fitted to the land. Less fuel and time, for example, are required to operate a machine on the level, on the contour, than up and down slopes, and there is less wear on the machine. The heavy costs of erosion, now running to approximately $3,844,000,000 a year in the United States also will be sharply cut.

Farming will become an expert profession; the inexpert and inept will be forced off the land. It is not impossible that the prospective farmer of the future will be required to satisfy society that he is qualified by training and experience to take on the trusteeship of a piece of productive land.

Most important, man will have learned the true value of his most precious natural resource. Tragically throughout history, the land has been the most neglected.

MAIZE SEED STORAGE

BY

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Introduction

It is the normal procedure in many corn (maize) growing areas in Jamaica to take off two crops annually, the Spring planting being carried out around April and reaped around August and the Autumn planting being made around September and reaped around March. To produce seed early enough to complete processing and marketing in time for the following planting it is essential to plant as early in the season as the rains permit. Even so it is not possible to prepare seed for marketing in time to satisfy the demand for the early plantings of the succeeding crop and these have to be supplied by seed carried over from the previous harvest. During the progress of the Government Scheme for the propagation and marketing of seed corn which was commenced in 1939 it has, therefore, been found necessary to store seed in quantities of up to a ton or more for five to six months to supply the early demand.

In the early stages of development of improved corn varieties it was found necessary to store seed stocks of breeding material for periods up to twelve months, and a sufficiently effective technique for this purpose was devised. The seed was sun dried to about 12% moisture content, fumigated overnight with carbon disulphide, aired in the sun and stored in air-tight 55 gallon steel drums containing a handful of naphthalene and a basin of fused calcium chloride (4). The calcium chloride was changed periodically until no further appreciable quantities of water were absorbed. By this means effective control of pest infestation was obtained. Even so, over a period of twelve months a loss of viability of 20% to 50% occurred. This must be attributed to chemical changes in the seed accelerated by the prevailing temperatures which was usually between 85°F. and 93° F. in the seed store during the day. It is to be expected that a considerable reduction of this viability loss could have been achieved by storage at lower temperatures but as this work was carried out during the war, refrigeration equipment was unobtainable and no experimentation on these lines could be carried out (2).

During 1944 when the demand for seed had reached 600 bushels per crop insufficient equipment was obtainable for storage of the necessary quantity of seed and storage in bags had to be attempted. The problem of controlling losses from pests immediately became serious. Damage by rodents was minimised by storage in a rat-proofed building and mice were trapped or poisoned. The main problem then became the control of weevils. Infestation of seed by the rice weevil (*Calandra oryzae* L.) had already occurred in the field in many of the seed consignments received into the store. This initial infestation was controlled by fumigation during processing of the seed but reinfestation occurred in the store, from two to four weeks after bagging. This presumably resulted in some degree from eggs which had survived fumigation as the seed was stored in crepe paper lined hessian or cotton bags. At the time insecticides which might conceivably have killed the eggs more effectively were unobtainable and three experiments were carried out to test the effect of readily available dusts.

Materials and Methods

In each experiment the variety used was J.S.Y., a yellow selection derived from the mixed red variety commonly grown in Jamaica, which is rather more susceptible to weevil infestation than the parent variety. The seed which had been selected, graded and fumigated as for market was dusted in a home-made dusting machine consisting essentially of a revolving drum, with generally 2 ozs. of each material per bushel (60 lbs.) of seed. Visual examination and germination tests indicated that no damage to the seed resulted in the process of dusting. The bagged seed was stored in stacks about five feet square and seven feet high, the bags lying on their sides on a slatted wooden platform raised about six inches from the concrete floor. Each treatment was replicated either four or five times, the several bags of any one treatment being distributed at different levels in the stacks as far as was possible. Weevil counts and germination tests were carried out at the initiation of each experiment and at determined intervals thereafter for 300 days or until the seed was no longer fit for use. Weevil infestation was determined by counting live weevils in five pound samples taken at intervals throughout each bag as it was found that after opening a bag the superficial layers of corn contained approximately 50% less weevils than the deeper layers. Germination tests were made on 100 weevil-free seeds from samples taken from the middle of each bag and were continued for six days. With the exception of the first experiment moisture content of the seed in each bag was determined when each sample was taken. The treatments used included the following dusts: kaolin (100), hydrated lime (200), Agrosan (70), Alkalox (calcined alumina) (100), ignited bauxite and Gammexane diluted with kaolin as well as mercury brick and an untreated control. The alumina, Alkalox A.G. 107/35/1 and Gammexane (666-P.C.1156) were furnished by Messrs. Imperial Chemical Industries Ltd. and the mercury brick by Messrs. F. W. Berk & Co. Ltd., England. The figures in parenthesis are the number of meshes per linear inch through which

the substances would pass. The selection of these treatments was primarily determined by the materials which were available at the time.

Weevil Control

Experiment I: This experiment was commenced on July 19th, 1944, and carried on until May 11th, 1945, a period of 296 days. During this period the weather was unusually dry, and the air humidity correspondingly low. Five replications of each treatment were made and freshly harvested seed was used. The moisture content of the seed at the initiation of the experiment varied from 11.5% to 13.2% averaging 12.7%; moisture contents were not determined subsequently. Table I gives the mean number of weevils per sample from each treatment at intervals from the commencement of the experiment.

None of the treatments was effective in complete prevention of weevil infestation but lime, Agrosan and bauxite were similarly effective in controlling this infestation at a satisfactory level. Whilst kaolin did have a depressing effect on weevil multiplication this was insufficient to bring about satisfactory control.

Experiment II: This experiment was commenced on October 26th, 1945, and completed on March 8th, 1946, a period of only 133 days, during the first part of which very wet weather and a correspondingly high humidity prevailed. During this experiment the moisture content of the seed, initially 12.8%, varied from 11.7% to 16.8%, averaging 13.2%. The seed used had been in storage about three months and was already moderately infested with weevils. In this and the following experiment only four replications of each treatment were made, the means of five pound samples of which are given as before in

TABLE I

WEEVIL POPULATION

(Mean of 5 bags)

Treatment	Number of days					
	0	64	96	138	163	296
Lime	0	1.0	0.4	1.0	3.0	9.6
Bauxite	0	0	0.6	0.4	3.8	1.0
Kaolin	0	0	0.4	14.4	50.4	130.8
Agrosan	0	0	0	1.0	8.0	5.2
Control	0	31.0	261.6	475.0	735.2	979.0

TABLE II

WEEVIL POPULATION

(Mean of 4 bags)

Treatment	Number of days				
	0	33	69	95	133
Lime	73.7	606.5	1,721.2	1,397.0	861.2
Kaolin	25.0	890.5	2,076.5	1,392.7	1,059.7
Agrosan	72.5	1,175.0	931.2	3,564.5	1,226.7
Alkalox	27.5	425.0	1,761.7	1,073.2	1,519.5
Gammexane	5.0	38.2	438.2	3,062.5	1,676.0
Mercury	40.0	234.5	1,253.2	1,394.2	922.7
Control	38.7	592.0	3,244.0	2,301.2	1,348.0

Table II. This experiment was terminated prematurely as it was found that after 133 days the corn was heavily infected by fungi (*Cephalosporium* spp. and *Penicillium* spp.) and in an advanced state of fermentation and had lost its viability completely.

The treatments differed somewhat from those used in the previous experiment. Bauxite was not used but three new treatments were introduced : Alkalox, Gammexane and mercury brick, a porous inert matrix impregnated with 27% mercury in droplets varying in size from 1 to 15 microns. One ounce of mercury brick was broken into about twenty small pieces which were distributed as uniformly as possible through each bag. The Gammexane was diluted with kaolin in the proportion of 1 to 19 before use, giving a concentration of 0.001% of hexachlorocyclohexane in the dust used. In this experiment each bag contained 100 lbs. seed on which the following quantities of dust were found sufficient to give an effective cover :—kaolin 1.5 ozs., lime 2.0 ozs., Agrosan 2.0 ozs., Alkalox 1.6 ozs., Gammexane 1.58 ozs.

It is apparent that no treatment was effective in destroying the initial infestation or in controlling weevil multiplication. It is evident that the conditions under which this experiment was carried out were such that the rate of multiplication of the weevils was considerably greater than the death rate resulting from the action of the treatments The only slight differential effect between the treatments appears in connection with Gammexane which had a depressing effect on weevil multiplication in the first two months.

Experiment III : This experiment was commenced on March 1st, 1946, and continued until December 10th, 1946, a period of 284 days. The weather during the period was slightly drier than normal and no extended wet periods occurred. Generally the climatic conditions were intermediate between those of the first two experiments but approaching rather more to those of the first. The moisture content of the seed was remarkably steady ; initially 13.3% and finally 12.8%, it varied in individual bags from 11.7% to 14.5% with a mean of 12.6% plus minus 0.4. Sound freshly harvested seed was used which was free from weevils.

The same treatments were used as in the second experiment with the addition of Gammexane at double the previous concentration. For convenience of handling the bags and to ensure that the seed was thoroughly coated with the dusts used, the same quantities were applied to 60 lbs. of seed instead of 100 lbs. In both this and the previous experiment a small residue of dust was left in the machine after treatment and dusting was adequate in both cases. The weevil data for this experiment are set out as before in Table III.

At the conclusion of the experiment the control and kaolin-treated seed, in addition to being heavily infested with weevils, were completely rotted and matted with a growth of *Penicillium* sp. All other treatments with the exception of one bag of lime and one of single Gammexane appeared to have produced effective control of fungal infection. Alkalox and double Gammexane showed very effective weevil control, only 9.1% and 3.2% of the seed showing signs of weevil attack respectively after 284 days. While the mercury treatment had kept weevil infestation at a low level, only 6.5% of the seed showing signs of damage, the seed was still otherwise apparently in sound condition. Lime and Agrosan treatments proved partially but insufficiently effective, the large majority of the seed showing signs of weevil attack.

It is evident from these three experiments that while weevil infestation of seed stored in bags in an open store can be controlled under normal climatic conditions, when those conditions are such as to prove

TABLE III

WEEVIL POPULATION

(Mean of 4 bags)

Treatment	Number of days								
	0	33	68	97	124	160	214	249	284
Lime	0	56.0	122.0	308.5	408.2	684.2	964.0	629.5	436.0
Kaolin	0	207.2	745.2	948.2	673.0	892.5	895.0	1,013.5	613.0
Agrosan ...	0	125.5	369.2	164.0	177.2	77.7	110.7	277.2	344.5
Alkalox ...	0	19.7	3.7	27.2	11.5	13.2	26.2	28.0	0
Gammexane single	0	3.0	34.0	50.7	162.2	107.7	504.0	889.0	1,285.0
,, double	0	6.5	0	24.7	27.5	0	0	23.2	0
Mercury ...	0	54.2	112.0	118.7	81.2	11.7	13.2	22.2	121.5
Control ...	0	232.4	1,339.0	929.2	992.2	1,007.7	847.7	412.0	634.2

abnormally favourable to weevil multiplication none of the treatments used were efficient. The controls became heavily infested within one to three months after setting up the experiment. Kaolin, while effective up to four months in favourable conditions, under average to poor conditions was useless. Lime, bauxite and Agrosan were a little better but were still not satisfactory for extended periods of storage or in damp weather. It should be mentioned that Agrosan is marketed not as an insecticide but as a fungicide for which purpose it has proved very effective as a seed dressing. Gammexane at single strength (0.001%) showed an anomalous behaviour. In the two last exeperiments control was efficient as compared with foregoing treatments in the early stages of the experiment. In the later stages, after three months in the last experiment, the control effect was lost, and in both these experiments the final weevil infestation was greater than in the control bags. Loss of the control effect may be attributed to the volatility of the active principal but there also appears to be a residual effect which operates in favour of the weevils. Gammexane at double strength (0.002%) and Alkalox gave effective control to a similar degree in the last experiment, a degree quite adequate for the requirements of commercial practice. With both these treatments as also with mercury the killing action was apparent as numbers of dead weevils were found in several of the bags. The mercury brick treatment was almost as effective as the last two treatments and though the final weevil population was higher the number of damaged seed was lower than in the case of double Gammexane. It would appear that the toxic action is relatively slow in effect as it will be noted that during the course of the third experiment appreciable surges in weevil multiplication occurred. This treatment is dependent on the maintenance of a vapour pressure within the bag and would probably have proved more effective had larger amounts of the brick been used or a more gas-tight pack employed.

Perusal of the weevil population figures shows that there is a considerable variation in any one treatment. In general, weevil increase corresponds to the sigmoid curve usually characteristic of biological phenomena of this sort (Fig. 1). Eventually population saturation is reached and the weevil count thereafter declines. This stage was not reached in the first experiment, but in the second and third a falling off is noted when the weevil count reaches about 3000 and 1000 per five pound sample respectively. (*Vide* Fig. 1 lime and control). Variations in the rate of weevil increase are probably due in part to variation in environmental conditions and to the cyclic effect of successive hatchings of weevil eggs, at least in the earlier stages. Counts made at more frequent intervals would probably throw light on the cause of such variations.

Germination

During the course of each of these experiments germination tests were carried out at the same time as each weevil count was made. The results of these tests are summarised in Table IV. The two bracketed entries should be discounted as those tests dried out before completion.

The tests were carried out on apparently sound seed selected from a sample from each bag and comparison of the trends in the four tables indicates that there is no consistent correlation between weevil population and viability loss. Storage of maize seed containing 8 to 10% moisture under insect-proof conditions in an air-tight drum produced a fall in germination percentage of 20 to 50% in a year. The loss of viability in the experiments under discussion was more rapid and is probably due to the

TABLE IV

MEAN PERCENTAGE GERMINATION

Treatment	Days—Experiment I							Experiment II				Experiment III								
	0	64	96	138	163	296	0	33	69	95	133	0	33	68	97	124	160	214	249	284
Bauxite	91	82	87	(53)	76	38	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lime	89	82	90	(49)	75	59	70	44	9	1	0	98	94	92	81	55	28	3	1	0
Agrosan	96	90	81	78	78	53	73	45	12	1	0	97	92	95	88	78	61	35	21	22
Alkalox	—	—	—	—	—	—	62	57	30	0	0	97	95	91	89	82	69	58	51	47
Mercury	—	—	—	—	—	—	67	64	38	12	1	97	93	91	90	72	50	34	29	20
Gammexane Single	—	—	—	—	—	—	67	57	39	9	0	97	90	93	91	86	78	39	31	16
Gammexane Double	—	—	—	—	—	—	—	—	—	—	—	98	92	88	87	77	68	53	48	45
Kaolin	95	86	93	71	68	29	67	31	4	0	0	95	84	43	3	0	0	0	0	0
Control	88	64	70	13	0	0	80	43	3	0	0	97	88	42	7	0	0	0	0	0

higher moisture content of the seed used, 12.0 to 13.0%. It is possible that decomposition products of the infested grain and dead weevils may have had a toxic effect and reduced viability in the later stages. The evidence on this point is suggestive but indefinite.

There is a clear relationship between treatment and rate of viability loss and such losses in these experiments are largely explicable on the basis of the combined action of time, involving the normal losses due to metabolism in stored grain, and treatment. In all cases the loss of viability is most rapid in the control bags, none of which contained any germinable seed after five months; kaolin-treated seed is little better. Except under the dry conditions of Experiment I lime showed little improvement over kaolin. Agrosan, mercury brick and single Gammexane were appreciably better than the foregoing and should prove satisfactory treatments for seed to be stored from 4 to 5 months under normal to dry conditions, in fact single Gammexane proved more effective than any other treatment over periods up to 160 days. Alkalox and double Gammexane were, however, considerably more effective in arresting viability loss than any other of the treatments tried. It has been suggested that Gammexane might prove directly toxic to the seed over a prolonged period but in the concentrations used here there was no evidence of this. It must be borne in mind, however, that under the damp conditions prevailing during Experiment II none of the treatments were successful in retaining viability over a sufficiently long period for practical purposes.

The experiments reported on open up a number of lines of further investigation into the question of weevil control of stored grain in the tropics. A number of new insecticides which have been developed since this investigation was carried out should be tried. Careful recording of the microclimate and observations at more frequent intervals should throw considerably more light on the biological processes involved. The possibilities of refrigerated storage should be explored. Variation in the type of pack where volatile insecticides are concerned should be tried. Efforts should be made to maintain the surrounding air humidity at as low a level as possible. The effects of decomposition products of both the seed and dead weevils on viability loss should be investigated.

Pending further investigation the following recommendations can be offered. Where only a few hundred pounds of seed have to be stored by a farmer from crop to crop, storage should be carried out in air-tight containers such as steel drums, kept in as cool a place as possible. Prior to storage seed should be fumigated with carbon disulphide and thoroughly aired. A handful of flake or crushed naphthalene should be distributed through the seed and a basin containing fused calcium chloride placed on top of the seed; the calcium chloride should be renewed periodically until it ceases to liquify. The liquified calcium chloride may be evaporated to dryness, ignited and used over again. (1, 3).

In commercial practice where large enough quantities of seed are handled to justify sufficient capital investment, in addition to the foregoing method of storage, the store should be equipped with a refrigeration plant; the optimum economic storage temperature, however, still awaits determination. (2).

In circumstances where the foregoing suggestions cannot be adopted and it is necessary to store bagged seed it is a primary consideration that the store should be rendered proof from rats and mice and should be well ventilated, if possible by exhaust fans. The roof and walls should be designed to obtain a minimum internal temperature as for instance by double construction and ventilation. The seed should be treated prior to bagging. In the foregoing experiments the treatments which have proved most effective are dusting with Gammexane dust containing 0.002% hexachlorocyclohexane or with Alkalox (calcined alumina). In designing stores and in storing seed it should be borne in mind that the essential considerations, so far as present knowledge of the subject indicates, are freedom from infestation at commencement of storage, avoidance of reinfestation by prevention of access of weevils, elimination of reinfestation from undestroyed eggs by treatment with an insecticide, and retention of viability by storage of dry seed in as cool and dry a place as possible.

Summary

A series of experiments are described on the storage in bags of shelled corn (maize) seed peviously treated with the following substances: kaolin, hydrated lime, ignited bauxite, Agrosan, calcined alumina, mercury vapour and Gammexane in two concentrations.

Records of the increase in population of the weevil, *Calandra oryzae* L., and loss of viability are analysed and compared.

Under exceptional climatic conditions, probably related to high air humidity, none of the treatments gave satisfactory weevil control. Under normal to dry climatic conditions various degrees of control were obtained and treatment with Gammexane or calcined alumina (Alkalox) provided satisfactory control of weevils and maintenance of viability for most commercial purposes.

Lines along which further investigations might proceed and provisional recommendations regarding storage methods are made.

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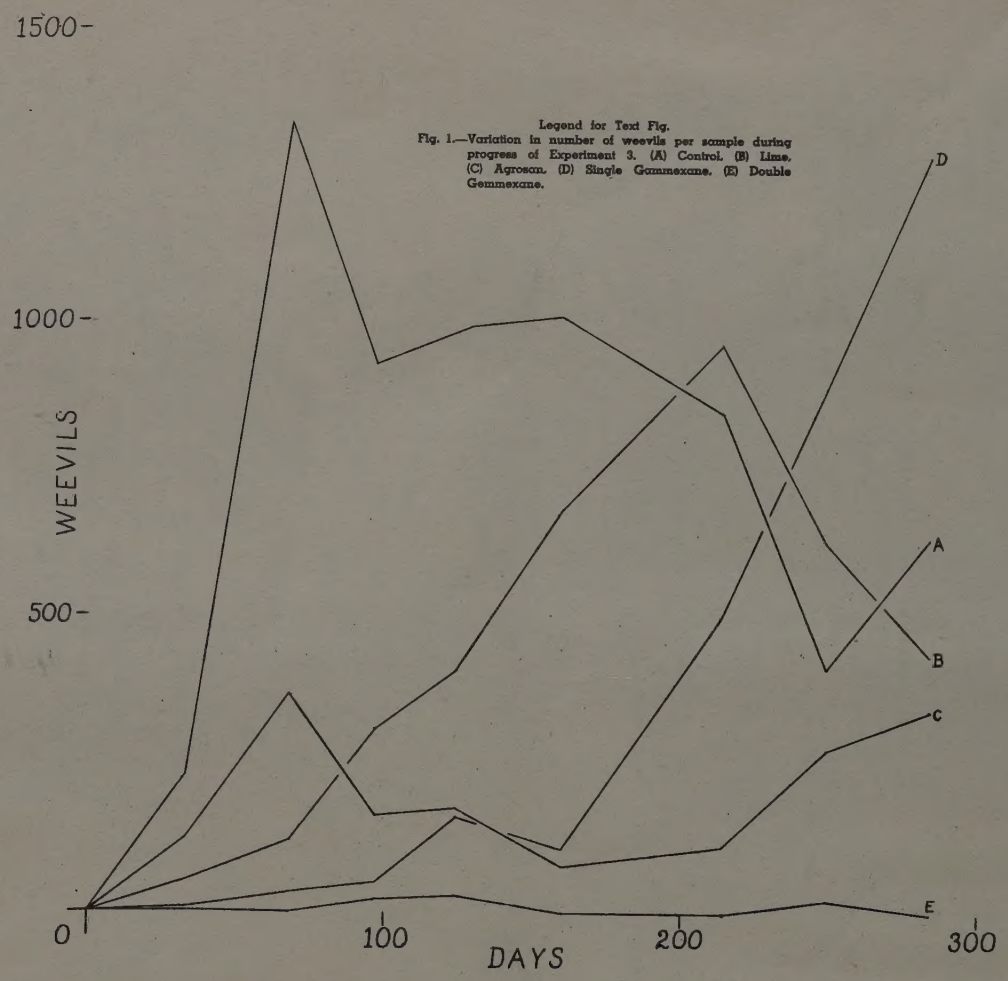

Legend for Text Fig.

Fig. 1.—Variation in number of weevils per sample during progress of Experiment 3. (A) Control. (B) Lime. (C) Agroscn. (D) Single Gammexane. (E) Double Gammexane.

EFFECTIVE RAINFALL AND SOIL MOISTURE IN TRINIDAD

BY

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Introduction

It is generally recognised that a bald statement of the annual amount of total rainfall, or even of its monthly or daily distribution, is insufficient for the purposes of ecological crop investigations, because in actual fact, only a relatively small part of the total rainfall is "effective" in controlling plant-growth. The variable fraction of the rain which is stored in the rooting zone may be estimated as the difference between the total rainfall and the sum of the several fractions which evaporate from the vegetation and the soil, which run off the land, and which penetrate deeply beyond the rooting zone. At the College Farm, it has been estimated, for example, that, for *fallow* land, about 60 per cent. of the annual rainfall evaporates without penetrating into the rooting zone and only about 6 per cent. is used to maintain the store of water in the top 10-inch layer of soil at complete saturation, leaving 34 per cent. which penetrates deeply or runs off the land or both. The store of water in the rooting zone is rapidly replenished once the soil is thoroughly wetted, provided the rainfall is of the "soaking" or penetrating kind. When the land carries a vigorously-growing bulky crop, such as sugar-cane, the magnitude of the evaporated fraction increases considerably and this factor must then be regarded as the main contributor to the debit side of "the balance sheet of the rainfall".

The amount of total rainfall and the quantity of water which evaporates vary greatly at different times of the year. During the wet season in Trinidad, evaporation is less than precipitation so that the soil within the rooting zone is kept in a condition of constant moistness and much water penetrates deeply when the drainage is not impeded, or partly runs away when it is not sufficiently rapidly absorbed. A regular downward flow of soil-water is thus initiated and maintained in well-drained soils during the wet season months and much soluble nutrient material, for example, nitrate, is consequently lost by leaching.

On the other hand, during the dry season, the small amount of monthly rain that falls is readily evaporated before it can penetrate deeply, and what moisture the soil has previously stored is also progressively evaporated, unless replaced by uplift from the sub-soil. The range of depth over which uplift is possible, however, is generally exaggerated. Actual measurements at Rothamsted have shown that upward water movement caused by capillarity is imperceptible over distances greater than 12 ins. for coarse sand, 24 ins. for fine sand and 27 ins. for heavy loam. It seldom exceeds 3 or 4 feet in any soil.

Various means for assessing the quantity of rain water that evaporates have been suggested. One of them, devised by Dr. E. C. Julius Mohr in Java and discussed in a previous article by the writer,* depends on the direct measurement of rainfall, run-off and percolation in cylinders of soil set up in the open. The actual amount of water evaporated is determined by difference. Data of this sort were collected by Mohr over a number of years, and it was found that evaporation may be approximately represented as a linear function of the rainfall, thus $E = c + fR$, in which the value for c is about 2.4 and of f about 1/8, for monthly rainfalls R inches. Mohr's formula may thus be written:

$$E = 2.4 + 1/8R$$

where E = evaporated water in inches;

and R = monthly rainfall, in inches.

This formula applies primarily to conditions at Buitenzorg in Java but comparison with evaporimeter data obtained at the College has shown that it may also apply generally to Trinidad, and therefore perhaps to other wet tropical countries as well. At the College, it was found that the percentage amount of the total rainfall which evaporates in an average wet season month is considerably higher than at Buitenzorg, namely, 60 per cent. compared with 28 per cent. in Java, and that the formula $E = 4.0 + 1/8R$, rather than that postulated by Mohr, more nearly applies to conditions in Trinidad.

The usefulness of Mohr's formula lies in the fact that it indicates what months are likely to be "dry" (that is, months when evaporation definitely exceeds the rainfall), and what months are likely to be "wet" (that is when rainfall exceeds evaporation). Other months which are moderately moist may be regarded as "intermediate". By applying his formula to the monthly rainfall data for some 2,500 rain-gauge stations in Java, Mohr constructed an "effective rainfall" map or "soil humidity" map of Java. The method of tabulation used was to classify the stations into six groups according to the number of wet months each with over 4.0 ins. of rain and the number of dry months each with under 2.4 ins., as follows:—

* The Evaluation of Soil Moisture. F. Hardy, *Trop. Agriculture, Trin.*, 1946, 23, pp. 66–75.

Group	*Dry period* (Number of months)	*Wet period* (Number of months)	*Designation*	*Percentage of stations* (Java)
I (a)	0	12	...Continuously wet	14
I (b)	0	12—6	...Continuously moist	17
II	1	11—4	...Weak dry season	15
	2	10—9		
III	2	8—4	...Marked dry season	43
	3	9—4		
	4	8—7		
IV	4	6—3	...Strong dry season	10
	5	7—4		
	6	6—5		
V	6	4—2	...Fierce dry season	1
	7	5—4		
	8	4—3		

Explanation of Mohr's Effective Rainfall Classification Scheme

GROUP I (a): *Continuously wet conditions:* Here there is always a surplus of rain above evaporation. This has a great effect on vegetation and on the processes of soil formation, since downward leaching of the soluble products of rock weathering and vegetable decay goes on uninterruptedly.

GROUP I (b): *Continuously moist conditions:* Here there are often several months (up to 6) when the rainfall is intermediate, so that in some years evaporation may equal or exceed the rainfall; otherwise the conditions differ little from the last.

GROUP II: *Weak dry season:* When there is only one dry month in the year, the soil can only dry out to a relatively shallow depth, but when their are two dry months, especially if preceded by an intermediate month, soil desiccation may be appreciable though not necessarily severe.

GROUP III: *Marked dry season:* Here the soil can dry out to considerable depth, particularly if there are four dry months with one preceding intermediate month.

GROUP IV: *Strong dry season:* Here soil desiccation is a prominent feature of the environment.

GROUP V: *Fierce dry season:* Only a few places in Java have such a dry climate as this. The group is relatively unimportant.

The influence of *temperature* is not taken into account in Mohr's scheme so that tropical mountain rainfalls are not amenable to classification in the same terms as those employed in the above group definitions. Nevertheless, within its obvious limitations, the scheme has many advantages over the customary simple division of the annual rainfall into arbitrary quantity grades, particularly as applied to problems of crop ecology.

An Effective Rainfall Map of Trinidad

Mohr's method of rainfall classification has been applied to the data compiled by F. M. Bain for 92 rain-gauge stations in Trinidad and published by the Trinidad Department of Agriculture in 1934. In the "effective rainfall" or "soil humidity" map of Trinidad appended to this article, only four out of the six groups recognised by Mohr in Java are represented. About 50 per cent. of the stations belong to Mohr's Group III (marked dry season); they have 2 or 3 dry months and 7 or 8 wet months, the remaining months being intermediate. There are no Group I (a) stations. About 20 per cent. of the total number belong to Group I (b), (continuously moist), and nearly as many belong to Group II, (weak dry season), but only about 10 per cent. belong to Group IV, (strong dry season). There are no Group V stations. The geographical distribution of the rainfall-recording stations is irregular, however, so that these figures do not represent the relative areal extent of the different rainfall categories in Trinidad.

(1) On the map, it will be noticed that, broadly speaking, the *continuously moist zone* occupies the greater part of the eastern half of the Island and stretches north to south down its whole length. It roughly coincides with the belt having annual rainfall above 80 ins., and with the highest elevated land forming the Northern, Central and Southern Ranges (see inset maps). It comprises the so-called "orchard belt" of Trinidad, which includes most of the Forest Reserves and the chief cacao estates.

(2) The *zone of weak dry season* merges with the continuously moist zone and forms a fringe on either side of it. Its demarcation is indefinite.

(3) The *zone of marked dry season* is conspicuous and characteristic. It roughly coincides with the belt of rainfall below 70 ins. per year, and with the low-lying land occupying the west of the Island, including the Caroni Swamp, the Caroni Savannah and most of the undulating Naparima District, stretching southwards to the Southern Range hills. It thus comprises practically all the sugar-cane lands. Westwards, it gives place to the *zone of strong dry season* which includes the westerly foothills of the Northern Range between Tunapuna and Port-of-Spain, and the western mid-coastal strip skirting the Gulf of Paria.

A Soil-Draining Map of Trinidad

The information afforded by an "effective rainfall" map, although it may be more directly applicable to ecological crop problems than the simple rainfall map, yet fails to take into account the differences that occur in degree of drainage impedence between different soil-types and over land surfaces having different slopes. In attempting to interpret an "effective rainfall" map of any region, it is thus necessary to superimpose it over a soil map in which degrees of drainage impedence are displayed, and in this way to try to predict "what may happen to the rain" that falls within each group-area of effective rainfall.

A soil drainage map has accordingly been constructed for Trinidad and appended to this article, from the reconnaissance soil map prepared by Dr. E. M. Chenery in 1939 which shows the distribution of the main soil-types provisionally classified on a drainage basis. This soil map has not yet been published, though on account of the principles of soil classification used in its preparation, together with a brief description of the chief soil-types, have previously been presented by the writer.* The soil drainage map accompanying the present article shows four drainage categories, namely, (1) free drainage, (2) partially-impeded drainage, (3) impeded drainage and (4) alluvial flats and swamps. These are briefly described below.

(A) *DRAINAGE FREE*: There are two main areas in Trinidad where the soil is freely drained although within each there are doubtless many localities where a considerable degree of impedence may occur, caused by depressed topography or the occasional presence of impervious geological substrata. These minor variations cannot be differentiated on a small map. The chief free-drainage areas comprise the mountains and foothills of the Northern Range and the dissected tablelands of the Mayaro and Moruga Districts in the south-east of the Island. Other free-draining areas of lesser extent occur in the Las Lomas and the Valencia Districts of the Northern Plain and around Siparia. The main soil-types represented in these free-draining areas are sandy; they chiefly comprise *Caroni Sand, Maracas Sand, Valencia Light Sand* and *Moruga Sand*.† Finally, some of the calcareous loams occurring in the Central Range, for example, *Montserrat Clay-Silt* ("Chocolate Soil") and *Montserrat Loam* ("Brasso Sand") are also classed as free-draining, as well as the deep sandy alluvial soils occurring in the Northern Range valleys (*River Fine Sand*).

Most of the areas of free-draining soils are located in the *continuously moist* zone of effective rainfall. They are thus highly leached and very acid and in general have a poor nutrient status, except where the parent rock is rich in mutable nutrient minerals, as, for example, in the case of the Montserrat District soils. In many instances, however, the parent rock is a loose sand or soft sandstone nearly devoid of all other minerals but inert quartz and the soils therefore show low productivity. Such sandy quartzose soils are common in the plains and in parts of the northern and southern mountainous country of Trinidad.

(B) *DRAINAGE PARTIALLY-IMPEDED*: The soil-types showing partially-impeded drainage mainly occur sporadically in the Northern Plain savanna country, the Naparima District and the Cedros Peninsula. They comprise *Piarco Sand-on-Clay, Princes Town Heavy Clay* and *Moruga Loam*. It is important to note that some of the areas indicated on the soil drainage map as *alluvial and swamp* should also be included in the partially-impeded class because they have been effectively drained by artificial means; for example, *Sangre-Grande Silty-Clay, Frederick Heavy Clay* and *L'Ebranche Clay-Silt*.

Most of the partially-impeded draining soils lie in the zone of *weak dry season* although a few stretch eastwards into the wetter zone or westwards into the next drier zone. Drainage impedence in the alluvial and swamp soils and in the savanna soils is mainly dependent on their situation in low-lying or flat topography but in the other soils it is chiefly the result of compaction or imperviousness of the soil parent material or parent rock which is either a calcareous clay or a massive silt. These soils in general are rated higher in the productivity scale (especially the soils derived from calcareous sediments) than those in the last group. Natural drainage impedence thus plays a minor part in their usefulness *provided they are suitably drained* by artificial

* A Provisional Classification of the Soils of Trinidad, by F. Hardy, *Trop. Agriculture, Trin.*, 1940, 17, pp. 153–158, with table of soil-type features. A land productivity map is issued separately with this article.

† The names of soil-types used in this article are Dr. E. M. Chenery's and are to be regarded merely as provisional. They are based on the names of the places where the soils were first examined and described.

means in the field. The low-lying alluvial types, however, occasionally suffer from flooding when rivers overflow their banks.

(C) *DRAINAGE IMPEDED*: The soil-types that show most drainage impedence are all impervious clays. Their parent rocks are sedimentary silt-stones or shales, sometimes calcareous (*Brasso Clay*), sometimes not (*Talparo Clay; Ecclesville Clay*). Two soil-types are alluvial (*Ortoire Clay. Nariva (Swamp) Heavy Clay*) and owe their drainage impedence chiefly to low relief. The rest occupy the Central Range and also the Las Lomas hills situated in the north of the Island, as well as a large part of the undulating Naparima District which stretches southwards from the Central Range to the Southern Range hills.

The impeded-draining soils occur in all four effective rainfall zones but most lie in the *continuously moist* zone and generally suffer waterlogging for the greater part of the year. Those that are derived from fine-grained sedimentary deposits which, together with massive reef limestones, form the hills of the Central Range, are prone to landslide (for example, *Brasso Clay*), and tend to slip away from the ridges so as to leave steep escarpments.* Their counterparts in the broad clay-belt comprising the Naparima District (*Brasso Clay, Talparo Clay*) form undulating country representing an old Pleistocene plateau of general elevation 200 feet. This peneplain is undergoing slow dissection by present-day river systems. They too are prone to landslide (slump, débris-slide) and to slow earth-movements (soil-creep, earth-flow).† These processes of erosion are greatly aided by soil cracking or fissuring which regularly affects the impeded-draining soils over the areas where marked dry seasons alternate with very rainy wet seasons, and frequently during dry spells in all zones when the land surface is exposed by clear-felling of natural vegetation for the purpose of establishing sugar-plantations or peasants' gardens.

The productivity of the impeded-draining soils is variable and depends initially on the nature of the parent rock. In general, calcareous claystones (for example, *Brasso Clay* parent rock) give rise to productive soils, classed as Grade II for cacao, citrus and sugar-cane. On the other hand, non-calcareous fine-grained sedimentary rocks (for example, *Talparo Clay* parent rock) produce only low-grade soils that are highly acid and very deficient in phosphate though usually rich in potash.

* Soil Erosion in Trinidad and Tobago: F. Hardy, *Trop. Agriculture, Trin.*, 1943, 19, pp. 29-35.

† Land Movements, F. Hardy, *Trop. Agriculture, Trin.*, 1940, 17, pp. 187-192.

Moisture Profile Investigations of Soils of Different Drainage Classes

During 1940-41,* the actual moisture profiles of eight important soil-types in Trinidad were investigated in the field at 17 different places growing forest or cacao, situated at eight widely-spaced localities, A to H, as shown on the accompanying maps. It ought now to be possible to employ the results obtained as a means of checking the generalisations submitted in the last section. Unfortunately, however, the rainfall during the period when the moisture profiles were investigated was abnormal. The wet season was rather dry (94 per cent. of the past 18 years' mean rainfall fell in the seven wet months) and the dry season was unusually dry (68 per cent. of the mean). Five of the eight localities (namely, A to E) lie in the *continuously moist zone*. These normally have no "dry" months with rainfall less than 2.4 inches but they have three intermediate months with rainfall between 2.4 and 4.0 inches and nine really "wet" months each with rainfall well above 4.0 inches. In the experimental period in question, however, there were three "dry" months (February, March and April) but no "intermediate" months within this zone. The remaining three localities (namely, F, G, H) lie in the *zone of marked dry season* and would normally have three "dry" months and two "intermediate", whereas, during the experimental period, there were five dry months (one was September), but no intermediate months. No locality in any other zone of effective rainfall was examined.

The procedure in the moisture profile studies was to collect soil samples at eight arbitrary depths from 6-foot pits dug once every two months at each site. Gross moisture contents were determined in the laboratory on these samples. The values obtained were converted to percentage volumes of water and air present at the times of sampling, employing porosity constants of the soils which were determined specifically for the purpose.

The eight localities are distributed among the three drainage classes and the eight chief soil-types as follows:—

(A) *DRAINAGE FREE*:

(1) *Caroni Sand*:

Locality G:

Siparia Teak Plantation (2 sites)

Locality H:

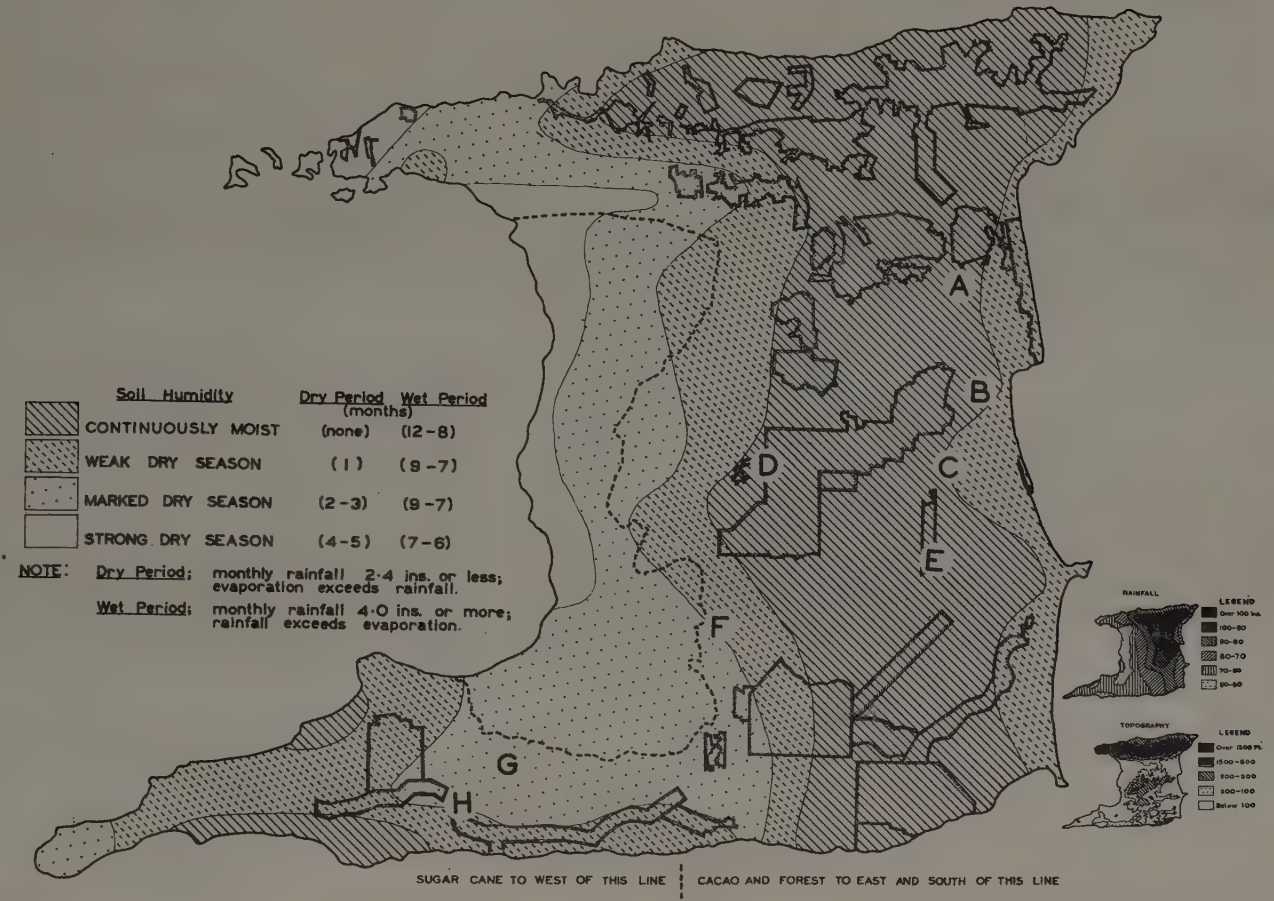
Southern Watershed Reserve: Old Teak Plantation.

(B) *DRAINAGE PARTIALLY-IMPEDED*:

(2) *L'Ebranche Clay-Silt*:

* The Moisture Profile in Some Trinidad Forest and Cacao Soils. E. M. Chenery and F. Hardy, *Trop. Agriculture, Trin.*, 1945, 12, pp. 100-115.

EFFECTIVE RAINFALL MAP
(Based on Mohr's Scheme)



SOIL DRAINAGE MAP OF TRINIDAD

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Locality B:
Marper Cacao Estate, Manzanilla.
Locality C:
Marcano's Vale Cacao Estate, Biche.

(3) Sangre Grande Silty-Clay:
Locality A:
Concord Cacao Estate, Sangre Grande.

(4) Marper Silt:
Locality D:
Central Range Forest Reserve, Brasso Venado.
Locality B:
Marper Cacao Estate, Manzanilla.

(5) *Princes Town Heavy Clay:*
Locality E:
Nariva Windbelt Forest Reserve, Ecclesville.
Locality F:
Adivinanza Cacao Estate, New Grant.

(C) *DRAINAGE IMPEDED:*

(6) Brasso Clay:
Locality B:
Marper Cacao Estate, Manzanilla.
Locality D:
Central Range Forest Reserve, Brasso Venado.
Locality F:
Adivinanza Cacao Estate, New Grant.

(7) *Ecclesville Clay:*
Locality D:
Central Range Forest Reserve, Brasso Venado.

(8) *Talparo (Red) Clay:*
Locality E:
Nariva Windbelt Forest Reserve, Ecclesville.
Locality B:
Marper Cacao Estate, Manzanilla.
Locality D:
Central Range Forest Reserve, Brasso Venado.

It will be noticed that certain localities display more than one soil-type; these were deliberately selected for convenience in sampling.

Summary of main results: The following notes describe the actual moisture conditions at the different sites during the experimental period.

(1) *FREE-DRAINING (SANDY) SOILS:*

Those examined are located near Siparia and occur within the *zone of marked dry season.* They showed considerable water deficiency and excessive aeration down to the full depth of the soil profile on each sampling occasion. These soils were physically dry even during the wettest weather because of their excessively free drainage. Doubtless the soils of similar sandy areas in other parts of Trinidad closely resemble them. Unfortunately, no free-draining soils were examined within the *continuously moist zone* where they occupy undulating forest land in the south-east and south of the Island and mountainous land in the Northern Range. It is believed, however, that, even in these wet regions, the sandy soils are seldom excessively wet.

(2) *PARTIALLY-IMPEDED DRAINING SOILS:*

(i) *Alluvial flats:* The examples occurring at localities A, B, and C in East Trinidad owe their lack of drainage mainly to low relief although they are all impervious clay-silts. They have been artificially drained by means of deep trenches. In spite of this, they were found during the rainy season to be almost completely saturated with water down to the full depth of the profile, except for the shallow surface crumby layer in which tree-roots are plentifully distributed. During the dry season, they were found to dry out slowly until, in March, cracks developed down to 15 ins. depth; afterwards drying was quicker. Whether these soils would show similar cracking in wetter, normal years is doubtful. Evidently, alluvial soils in Trinidad ought to be provided with surface drains in order to cope with spells of excessively wet weather and with occasional floods. Their productivity would seem to depend mainly on the maintenance of a thick layer of soil crumb protected by leaf litter. Where the natural replenishment of organic residues is inadequate, leaf production might be increased by judicious manuring, or leaf fall augmented by mulching or organic manuring, otherwise soil fertility may rapidly diminish.

(ii) The partially-impeded draining soils which were investigated in *hilly country* included two (at localities B and D) derived from calcareous silt. The soil-type which they represent (*Marper Silt*) is among the most productive soils of Trinidad, although limited in area. These soils were found to respond readily to rainfall fluctuations; they rapidly filled up during rainy spells and just as rapidly emptied in dry weather, even though situated in the *continuously moist zone.*

(iii) The two remaining examples of this drainage class occur in *undulating country* (at localities E and F) and are derived from marlstone; they also represent a productive soil-type (*Princes Town Heavy Clay*) notable as a first-grade sugar-cane soil. Because of their crumby structure, these soils possess high infiltrability and permeability. They were found to be seldom waterlogged for long, although they exhibited high but shallow perched water-tables during the wettest months.

(3) *IMPEDED-DRAINING SOILS:*

These occur at localities B, D, E and F, within the *continuously moist zone* and are all *hilly-land* clay soils. They were found to differ greatly in their

water relations because of differences in surface structure, in degree of slope, and in non-capillary porosity, partly attributable to cracks.

Three of the examples investigated at localities B, F and E (*Brasso Clay, Talparo Clay*) exhibited high infiltrability, not because of the occurrence of a crumb layer, but because the surface soil was sandy. They occupy flattish hill-crests. Their permeability decreases markedly down the profile. These soils were found to fill from below upwards when the rains came; they remained replete with water throughout the wet season and only their surface layers to 12 or 18 inches dried out during the following dry season. Such conditions are not conducive to high productivity. Root distribution is confined to a relatively shallow surface layer comprising soil crumb and litter, and this must be maintained intact, otherwise fertility might diminish.

Two of the examples investigated at localities B and D (*Brasso Clay*) exhibited low infiltrability through loss of surface crumb-soil by erosion. They occupy steeply-sloping ground. Before the rains came, they were deeply cracked and rapidly filled up with water during the early part of the wet season but the cracks soon sealed so that most of the later heavy rains ran off the surface. A high perched water-table was continuously present during the greater part of the wet season. Below the 24 to 36 ins. depth, the soil was relatively dry. Here again, the moisture conditions are not conducive to high productivity; erosion seems to have been the main cause of the loss of infiltrable and retentive crumby surface soil.

Finally, two examples investigated at locality D (*Ecclesville Clay* and *Talparo Clay*) resembled the last but in these cases water-penetration was negligible because of (a) low surface infiltrability (caused by extreme compaction and puddling by beating rain following exposure and severe erosion), (b) the rapid sealing-up of the upper parts of the dry season cracks, and (c) the exceptionally steep slope. These profiles were consequently found to have remained nearly dry for the greater part of the wet season as well as during most of the dry season. No perched water-tables developed, and the bottom part of the cracks apparently remained permanently open and the soils were excessively well aerated. This unusual state of affairs is unique among the profiles examined and was quite unexpected when this investigation was started. Subsequently enquiry revealed the fact that similar "hard dry clays" are common in steeply-sloping forest lands in Trinidad lying within the continuously moist zone. Their occurrence indicates the need for caution when attempting to predict what happens to the rain that falls with known intensity and periodicity over land whose topography varies and whose soils differ markedly in infiltrability because of the diverse structures exhibited by the subsoils, parent materials and parent rocks.

Conclusions

It is evident from the results obtained by actual periodic measurements of moisture profiles that, in Trinidad, the physical features of site and soil largely decide "what happens to the rain" after it has reached the land. Under natural conditions in the undisturbed Evergreen Seasonal Forest (which is the characteristic primeval vegetation of the wettest parts of Trinidad) a large proportion of the rain evaporates from the tree foliage without ever reaching the land. Furthermore, probably most of the rain which passes through the forest canopy or runs down the tree-trunks is absorbed by the spongy leaf-litter and crumb-soil and none runs away, except perhaps during the heaviest showers. Any impairment of the absorptive properties of the surface layer of the soil, brought about for example, by loss of litter and crumb through wastage or erosion may greatly reduce the soil's infiltrability, so that surface run-off is enhanced and erosion consequently intensified. Such a cycle of deterioration may be initiated in the forest by indescriminate felling and burning for the purpose of establishing cacao and citrus plantations or peasants' gardens, or by injudicious thinning carried out during sylvicultural operations in forest reserves, or by drastic exploitation of timber. That such an undesirable condition has developed in many forest and cacao areas in Trinidad occupied by soils having impeded drainage, is indicated by the data obtained in the moisture profile investigations. The loss of infiltrability of the land surface may thus partly explain the diminution of cacao yields in some districts, the deflection of the forest vegetation growing on the "hard dry clays" of the south, and perhaps even the failure to re-establish Cedar in forest areas where it formerly thrived. Finally, as regards flat lands in which Trinidad abounds, there would appear to be no other solution to the problem of flood prevention except through the provision of suitable catchment drains and field drains to cope with excessive water in the wetter rainfall zones and with surplus run-off water which the impairment of the soil surface on the hills has enhanced.

Summary

(1) This article describes an "effective rainfall" map and a "soil drainage" map of Trinidad. The first was constructed from mean monthly rainfall data for 92 stations published by the Department of Agriculture and the second from a provisional soil-map of Trinidad prepared by E. M. Chenery in 1939.

(2) The *effective* rainfall map shows the distribution of four groups of stations, namely, (I) continuously moist, (II) weak dry season, (III) marked dry season and (IV) strong dry season, differentiated by the application of Mohr's evaporation formula, $E = 2.4 + 1/8R$, for monthly rainfalls at Buitenzorg in Java.

(3) The *soil drainage map* shows the distribution of three soil categories having, (A) drainage free, (B) drainage partially-impeded and (C) drainage impeded. Examples of pedological soil-types belonging to each category are named and their occurrences briefly described in relation to the distribution of effective rainfall, topography and parent rock. Special mention is made of alluvial flats and swamps which are widespread in Trinidad.

(4) The drainage conditions at 17 different sites, representing 8 soil-types located within the continuously moist zone and the zone of marked dry season, where moisture profiles had previously been quantitatively studied over a period of 14 months, are considered in relation to effective rainfall. It is concluded that certain impeded-draining soils have apparently become impaired through erosion which has reduced surface infiltrability so that the profiles remain dry even in the wet season.

(5) The necessity for providing catchment-drains and field drains for preventing floods within alluvial flats is indicated.

(6) The importance of maintaining intact the litter and crumb layer over the soil surface is stressed. This layer, where present, imparts high infiltrability to forest and cacao lands.

LONGEVITY OF BAMBOO SEED UNDER DIFFERENT STORAGE CONDITIONS

BY

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Flowering and fruiting of clump bamboos occur at intervals ranging from 20 to 80 years or more from seed (1). It is not surprising, therefore, that the literature contains little or no information on the best storage conditions of bamboo "seed", a caryopsis. In February and March of 1945 and again in 1946 many clumps of *Bambusa arundinacea* Retz. on the station grounds flowered and developed fruits, (Figs. 1 and 2.) This species is extremely thorny and is of little economic value except for fence rows or windbreaks. Nevertheless the opportunity to study longevity of the seed under different storage conditions was considered worth while because the results, no doubt, are applicable to other bamboo species.

Seed was harvested by shaking fruiting culms over a canvas. In 1945, with exception of two samples the seed was stored in sealed quart fruit jars. Granular calcium chloride was placed in the bottoms of the jars as a drying agent. About 1 inch of cotton batting was placed on top of the calcium chloride and samples of the bamboo seed were tied in cheesecloth bags resting on the cotton. Seed samples stored in this manner were exposed to four temperature ranges: (1) Room temperature ranging from 70 degrees to 90 degrees F., and controlled temperatures of (2) 70 degrees to 80 degrees, (3) 60 degrees to 70 degrees, and (4) 50 degrees. In addition, one sample was stored in a dessicator at room temperature over potassium pyrogallate solution which absorbed oxygen and carbon dioxide. Another sample was stored as a control in an open fruit jar at room temperature. The initial moisture content of the seed averaged 18 per cent. Periodically, 100 seeds were removed from each treatment and these were germinated on filter paper placed on moist sphagnum moss in petri dishes under room conditions. Small variations in germination of 100 seed would be expected by chance and only large differences can be considered significant although it is interesting to point out the small differences also.

The results of the germination tests for the seed collected in 1945 are presented in Table 1. Variations in the percentage of germination occurred throughout the experiment. In some cases the percentage increased somewhat with time but such increases were usually temporary. The percentage germination of seed stored over calcium chloride did not decrease appreciably after 202 days of storage with the exception of that held at 70 degrees to 80 degrees F. Seed stored over potassium pyrogallate solution and that of the control showed a definite decline in viability after 108 days in storage. Under these last two conditions no seed germinated after 202 days of storage.

The 1946 crop of bamboo seed was also stored in fruit jars except for one sample placed in a dessicator over a solution of potassium pyrogallate. Hydrated lime and powdered charcoal were used in addition to calcium chloride as drying agents. For controls, one sample of seed was exposed and another sample was sealed tightly in a jar without a drying agent. The original moisture content of the seed averaged 23 per cent. Half of each sample was dried in an oven to a moisture content of 12 per cent. Samples of seed at these two moisture contents were exposed to room temperatures ranging from 70 degrees to 90 degrees F. and in a refrigerator ranging from 44 degrees to 50 degrees. The control seed sample and that stored over potassium pyrogallate were exposed to room temperature only. The initial germination of oven-dried seed averaged 79 per cent. and that not dried 88 per cent. Results of later germination tests are presented in Table 2.

TABLE 1

THE EFFECT OF SEVERAL STORAGE TREATMENTS ON LONGEVITY OF **Bambusa arundinacea** SEED COLLECTED IN 1945

Storage conditions		Percentage of seed germinated after being stored for						
Seed stored over	Temperature	9 days	17 days	27 days	64 days	108 days	160 days	202 days
	°F	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent
Calcium chloride	Room ...	76	79	76	78	80	80	76
Calcium chloride	70-80 ...	80	86	90	85	86	83	61
Calcium chloride	60-70 ...	76	76	73	88	84	74	76
Calcium chloride	50 ...	75	81	83	80	75	76	79
Potassium pyrogallate solution ...	Room ...	81	64	78	71	79	55	0
Control, exposed	Room ...	81	71	88	81	83	46	0

Note :—Room temperatures ranged from 70 to 90 °F.

TABLE 2

EFFECT OF SEVERAL STORAGE TREATMENTS ON LONGEVITY OF **Bambusa arundinacea** SEED COLLECTED IN 1946

Storage conditions			Percentage of seed germinated after being stored for		
Seed stored over	Temperature	Oven dried	72 days	148 days	227 days
	°F		per cent.	per cent.	per cent.
Calcium chloride	Room	no	68	78	81
Calcium chloride	Room	yes	45	83	87
Calcium chloride	44-50	no	66	76	79
Calcium chloride	44-50	yes	51	72	78
Hydrated lime	Room	no	65	0	0
Hydrated lime	Room	yes	60	0	0
Hydrated lime	44-50	no	72	83	66
Hydrated lime	44-50	yes	61	86	84
Charcoal	Room	no	70	36	0
Charcoal	Room	yes	66	30	0
Charcoal	44-50	no	69	74	86
Charcoal	44-50	yes	68	81	77
Potassium pyrogallate solution	Room	no	70	0	0
Potassium pyrogaliate solution	Room	yes	63	0	0
Control, sealed	Room	no	79	0	0
Control, sealed	Room	yes	67	0	0
Control, exposed	Room	no	74	72	36
Control, exposed	Room	yes	69	76	21

Note :—Room temperature ranged from 70 to 90 °F.

FIG. 1.—Culms of *Bambusa arundinacea* which flowered profusely, as above, shed their leaves and died. Usually all culms within a clump flowered simultaneously. In the lower centre background there is foliage of another clump of the same species which is not in flower.

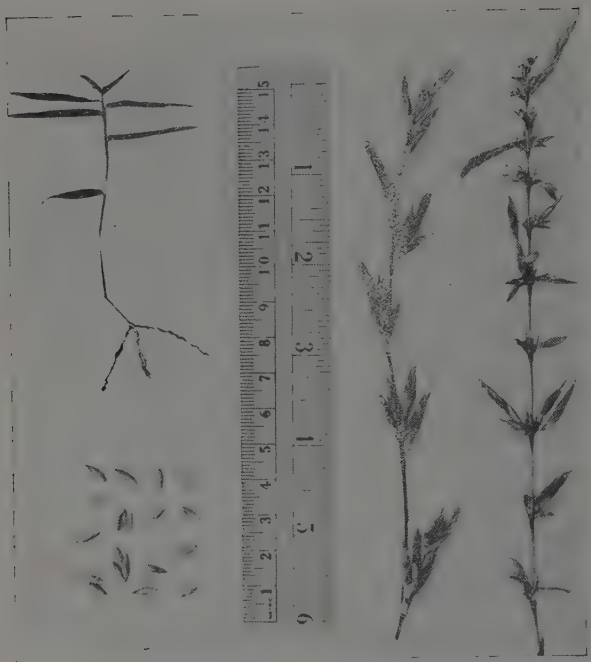

FIG. 2.—Two twigs of *Bambusa arundinacea* are shown at the right in flower and developing fruits. The mature seed (a caryopsis) at the lower left, appear similar to oats. At the upper left is a seedling plant about 3 weeks after germination.

FIG. 3.—Plants above are from *Bambusa arundinacea* seed collected in February, 1945. Seedlings 2 to 3 feet in height were planted 6 feet apart 6 months previous. The rapid growth has already made this planting useful as a windbreak. (Photograph taken October, 1946.)

At the end of 72 days of storage, seed which had not been ovendried had a higher percentage germination than seed which was dried, although the differences were often small. After 148 days, seed stored at room temperature over hydrated lime, potassium pyrogallate, and sealed in jars without a drying agent did not germinate. Under the other conditions, four oven-dried samples had greater germination than seed similarly stored but not dried. After 227 days the greatest germination followed storage over calcium chloride at room temperature. Under these conditions seed which had been dried germinated slightly better. Refrigeration at 44 degrees to 50 degrees apparently did not increase the effectiveness of calcium chloride in prolonging viability. On the other hand, refrigeration of seed over hydrated lime and over charcoal increased longevity. A small percentage of seed of the control sample exposed to room conditions germinated after 227 days.

In these tests the most practical method of preserving viability of bamboo seed was storage over calcium chloride at room temperature. Storage over hydrated lime or over charcoal was also a good method if refrigerated. Drying of the seed to a moisture content of about 12 per cent. definitely increased longevity when stored over hydrated lime under refrigeration. In other cases there was little or no advantage gained by drying. When no drying agent was used, exposed seed retained viability longer than seed sealed airtight.

Bamboo seed offers an easy and economical method of propagation. A large quantity of seed of *Bambusa arundinacea* from the 1945 crop was planted in soil at a depth of ¼ inch within a greenhouse. After about two months the plants were 8 to 10 inches in height and were then transplanted to gallon cans placed under partial shade. Eight months later each plant was 3 to 4 feet in height with numerous side branches and additional shoots. These were planted for a windbreak at 6-foot intervals and immediately began rapid growth. Six months later a dense hedge 10 to 12 feet in height had developed, as shown in Fig. 3. It is apparent from these results that many advantages would be gained by the discovery of a means to induce flowering and seeding of bamboo and thereby reduce the present high cost of propagation by vegetative methods.

Reference

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ERADICATION OF MOSQUITOES AND TSETSE FLIES

An outstanding instance of mosquito eradication is the elimination of *Anopheles gambiae* Giles from Brazil. This species was found in Brazil in 1930 and serious outbreaks of malaria occurred in a small area that year and in 1931. It did not attract attention again until 1938 when it caused the deaths of about 20,000 persons in the 12,000 square miles it then occupied. The Brazilian Ministry of Health, co-operating with the Rockefeller Foundation, concluded a successful eradication programme by the end of 1940. Apparently a very successful campaign is also being waged in Brazil for the complete eradication of the yellow-fever mosquito, *Aedes aegypti* (L.). An intensive programme has been under way for several years and many large areas now seem to be free of this species.

In 1943 *Anopheles gambiae* was reported to have caused more than 130,000 deaths in Egypt, having extended its area from the Sudan along the Nile to within 200 miles of Cairo. The Egyptian Government, co-operating with the Rockefeller Foundation, assigned more than 4,000 personnel to the task of eradicating this species, which was reported accomplished by the end of 1945.

In Southern Rhodesia the tsetse fly, *Glossina morsitans* Westw., has been eradicated from more than 6,000 square miles during the past 10 years, following a programme based on the destruction of all big game in fenced belts 10 miles in depth and 100 or more miles wide. A different method has been successful on the Gold Coast in West Africa against *Glossina palpalis* R.-D., and *G. tachinoides* Westw. From 1940 to 1945 more than 1,000 square miles in an area of very heavy incidence of sleeping sickness were freed of these flies by clearing stream banks of certain vegetation.

In Zululand in the Union of South Africa, where *Glossina pallidipes* Aust. is the predominant species, a large-scale experiment in eradication is now being conducted on 40 square miles of bush country, applying a DDT solution by airplane. A recent letter from Dr. Rene du Toit, Veterinary Officer, gives some very interesting details. As to results, he says : "In the Mkuzi Reserve 5 applications spaced at two-weekly intervals have to date resulted in the almost entire elimination of the tsetse flies in the area..... So far as other species of insects are concerned the effect upon *Anopheles gambiae* has been profound. This is a notorious malaria area and not a single case of malaria has developed in a personnel of approximately 50 camped in the area throughout the summer months." Thus it would seem that in any area in which tsetse flies are eradicated by chemical means malaria might also disappear.

(Abstracted from "Achievements and possibilities in pest eradication" by C. Lyle, *Jour, Econ. Ent.* 40 : 1-8, 1947.)

COFFEE PLANTING IN SOUTH INDIA

An Example of Conservatio Agriculture in the Tropics

BY

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There can be no question that the discovery of sound conservative agricultural systems for tropical soils is fundamental to social development in the warmer zones of the earth. Jacks & Whyte in their brilliant survey "The Rape of the Earth" are somewhat pessimistic. "It is doubtful whether any known method of economic land utilisation will produce a stable granular structure in humid tropical soils, or whether any economic application of manures can replace the luxuriant wild vegetation as an adequate fertiliser and stabiliser of the land." Any example which suggests a solution of this problem is therefore of general interest, even if it be only applicable to a limited range of economic crops. Moreover, a solution for a limited range of crops may offer suggestive lines of thought applicable to other products growing in similar circumstances. On this account, some details of the cultivation of coffee in South India would appear to be worth consideration, more especially as its special features from the point of view of soil conservation do not seem to be widely known. Thus, Jacks & Whyte speak of the "Bergcultures" of the Dutch East Indies as "the most successful example of intensive cultivation of tropical forest soils. . . where erosion has been checked and the soils are still producing good crops of coffee, tobacco, rubber, etc., after forty or more years of continuous cultivation," and go on to remark "it is doubtful, however, whether they would have survived, even under the exemplary treatment they have received, had they not been mostly very young soils derived from recent volcanic eruptions, containing reserves of plant food considerably greater than those found in older tropical soils." Nevertheless in South India, there is at least one coffee estate still in economic production which was opened in 1840, and a considerable number opened between 1860 and 1880, on soils derived from gneiss which are in no sense rich. On one estate known to the writer, the Manager has been engaged in recent years in replanting for the second time land originally opened in coffee between 70 and 80 years ago, and with every indication of success. Much of this estate is on steep slopes and has an average annual rainfall of about 150 inches, two-thirds of which falls in the three South West Monsoon months.

It will be agreed, I think, that these are striking results for what are usually somewhat euphemistically known as "permanent" plantation crops. They have not been quoted, however, in any competitive spirit with the intention of decrying the very successful developments in the Dutch East Indies, from which they differ in several important particulars. The "permanent" agriculture of the Dutch East Indies has been based primarily on the conscious application of principles of sound land use, derived from the scientific and technical research for which the Dutch have been famous. The coffee industry in South India has succeeded in coming to terms with the soil largely unconsciously, as a result of the art of a series of British farmers and gardeners who applied their skill to the development of the coffee industry. It is perhaps not without significance that R. H. Elliot, who developed the Clifton Park system of farming, was one of the pioneer coffee planters in Mysore State, before he returned to farm so successfully in his home country.

This empirical growth of a farming system involved a good deal of trial and error, which has left its mark in impoverished soils and abandoned estates. Practical skill, when it has been effectively applied, has rarely been accompanied by theoretical generalisation. One can see the same phenomena of soil conservation as an incidental feature of the agricultural system, as Jacks & Whyte noted in the case of the rice cultivation of South and Central China, associated with other practices revealing a lack of conscious appreciation of what was really happening to the soil. The result is that though there are numerous cases of successful cultivation of coffee on a sound conservation basis, there are also many cases of failure and the persistence of practices which are indefensible from the point of view of soil safety.

The basis of the system in its ideal form was the insertion of the economic crop—coffee—within the existing plant association—evergreen forest. How the early planters arrived at this method of cultivation is uncertain, but it is probable that they observed the healthy growth of coffee plants in the groves surrounding the hill villages of the western districts of Mysore State, and adapted it for the more extensive cultivation of the crop. It is clear that the pioneers attached great importance to the selection of land on the biological criterion of the existing plant associations. The oldest estate in Mysore, as far as is known, consists of a series of patches of land, each of some 20 or 30 acres, the intervening areas having been left to later comers, much to the regret of the present owners, and to the confusion of the Management.

In order to clear the land sufficiently for planting, the undergrowth was cut and allowed to decay. It is well authenticated that the majority of the estates which have lasted in economic production for very long periods were opened without burning the undergrowth. This permitted the preservation of the humus cover and of course avoided the risk of damage to the upper storey of the forest which was to be retained.

The planting system was close, never more than 6 ft. x 6 ft., and in the oldest estate no regular planting lines were laid out. While it is probable that the reasons for such close planting were economic, the fact was that a quick cover of the ground was obtained which incidentally provided that protection of the soil formerly ensured by the natural undergrowth.

Management of the estate involved the care and regulation of the overhead canopy to secure as high a crop as was consistent with its preservation. It is here that a sound instinct for the care of the soil was evidenced by the pioneers since it is certain that the density of shade which become generally regarded as sound, permitted a light supply well below the optimum for maximum cropping. At the same time, this density ensured a canopy capable of maintaining the mulch supply and protecting the soil from the impact of the heavy rain storms which are common in the coffee districts.

Again, sound instinct appeared to have discouraged any undue soil disturbance . Under the system of management soil 'tilth' was generally preserved and observation alone was sufficient to indicate that further disturbance by implements was unnecessary. However, it must be admitted that shortage of labour may have been a factor in protecting the soil from the damage which excessive cultivations can cause. Even if this was the case, the experience was correctly appreciated, applied and passed into the nucleus of good coffee planting practice.

Successes in these early attempts, together with general economic conditions, encouraged considerable extension of the industry in South India in the 1860's parallel with the development in Ceylon. Much of this development ignored the experience of the pioneers in Mysore and land was felled and burnt and the coffee planted in the open. All that is left of this phase of the industry is poor secondary forest or thickets of the exotic *Lantana camara.*

At the same time, there were good coffee 'farmers' who learnt the lesson of the early pioneers and developed it to bring under cultivation a wider area where forest conditions were somewhat less favourable than in the originally selected localities. The essence of their technique was the use of shade and selective felling of the jungle—mixed monsoon forest—which was opened up. Of course, the use of shade trees is not peculiar to the South Indian coffee industry, nor did it originate there, but there were undoubtedly special features characteristic of this particular branch of plantation agriculture, some of which have been independently "rediscovered" in other branches and other countries.

In the first place, the clearing of the land for planting was limited to the removal of the undergrowth and of trees which were recognised as bad for coffee. The extent of clearing naturally depended on the nature of the forest and the opinion of the planter but the best practice erred on the side of conservation. Where the felled land was burnt, it was as light a burn as possible in the interests of preventing damage to the trees left as the basis of the shade. Incidentally, of course, damage to the surface soil was also limited. On the other hand, planting rows were laid out, up and down the slope and little was done about drainage and disposal of surplus water illustrating the lack of appreciation of the soil erosion danger. Where circumstances required extensive felling there were undoubtedly serious soil losses until the establishment of the close planted coffee and the new shade covered the ground and permitted some recovery.

The planting of shade, where overhead cover was thin and absent, accompanied the planting of the coffee. Unlike the shade policy of most plantation agriculture, the choice of trees was catholic and in no way limited to leguminous species. A list of trees used or tolerated as shade by South India coffee planters would be a very long one, including indigenous species of *Albizzia, Dalbergia, Acrocarpus, Adenanthera,* among leguminous trees and of *Ficus, Cedrela, Bischofia, Terminalia, Zizygium, Artocarpus,* among the non-legumes. Even trees known to be far from ideal for coffee were sometimes left if their removal would leave the area very sparsely covered.

The choice of trees was based on trial and observation, and there was much variation in preferences in different localities, often close together. An intimate knowledge of the local tree flora was the hall mark of a good planter, even though he only knew the vernacular names. One planter, Graham Anderson, added much to the knowledge of the trees of western Mysore in his study of the coffee shade problem, and Robert Elliot showed an extensive knowledge of the same subject in his "Gold, Sport and coffee planting in the jungles of Mysore".

A mature coffee estate of this period, many of which can be seen in Mysore and Coorg at present, shows a variety of trees scattered more or less irregularly throughout the cultivated area to provide a more or less uniform continuous canopy of shade. The regulation of the density of this canopy, with regard to the health and productivity of the coffee, and to the variations in foliage of the species comprising it, call for nice judgment and represents one of the most exacting tasks of the planter. It is not too much to say that the success of a coffee planter in South India rests on his management of shade.

The best of these planters realised that no shade policy could be static and a striking feature was the existence in estates of trees of varying age, as a result of continuous planting of suitable trees where gaps occurred, or where there were signs of the aging of existing trees. To the tidy eye of the gardener or orchardist, a South Indian coffee estate looks a heterogeneous collection of trees of all ages and varying species, but it is on this attempt to create a plant community around an economic crop that the industry's success has rested.

Changes in method followed upon the introduction of two easily propagated exotic trees, *Erythrina lithosperma,* and *Grevillea robusta.* These trees, the one leguminous, the other non-leguminous, have proved of great advantage to the industry, but have made possible some less satisfactory deviations in management. They have simplified the problem of opening up land in coffee and permitted the extension of the area available for planting. In the process, however, two cardinal principles have all too frequently been overlooked. These are the importance of a mixture of species in space and of individuals in time—principles which were in effect the characteristic features of the South Indian coffee shade system. There has been a tendency to treat the shade as a static problem on a geometrical plan, to be solved by clean clearing, and planting a limited number of species on a regular system. Insufficient attention has been given to the necessity for succession and to the advantages of the maximum variety of species. Some of the older estates planted in this way are finding difficulties owing to the excessive age of the shade stand and the absence of younger trees suitable to take over the task of providing the canopy.

Nevertheless, the use of these two exotics in combination with the older mixed indigenous shade, and with appreciation of the importance of succession, does appear to offer a satisfactory solution of permanent agriculture under the conditions of the hill areas of South India.

The devlopment of this agricultural system owes little to applied science, but there is strong evidence that an examination with a view to its thorough understanding may lead to still greater improvements and to the simplification of management. The work of Nutman in East Africa has shown that there is a sound biological basis for the use of shade in coffee cultivation, even apart from its influence on soil conservation. Carefully controlled studies of shade density and canopy composition are difficult but may be expected to throw considerable light on the most favourable management if appropriate technical methods can be developed. Such investigation may lead to valuable generalisation and open the way to the wider application of "under storey" agriculture in the tropics. There are indications that other crops can be grown under similar conditions. Cardamoms are most successfully grown when inserted into a suitable forest association, and pepper can also be cultivated in the same way. The use of shade in tea is now very general in South India, but the application of the principles of diversity of species in space and of succession in time—the more characteristic features of the best practice in coffee planting—has been less appreciated. Shade has, of course, always been important in the cacao industry in America and is employed largely in the younger stages of Cinchona, rubber and citrus cultivation in India. The value of shade in mature rubber has been the subject of comment by Bertrand in Ceylon. In connection with this problem, a study of the mixed cropping commonly to be seen in the foot hills of the western ghats would be of interest. This mixed cropping based on an upper storey of palms—areca and coconut—with *Piper betle* or pepper as a climber on living standards of *Erythrina indica* and with robusta coffee, or tapioca or various yams in the lower storeys, offers possibilities of sound land use with economic crop production under conditions where clean clearing and single crop cultivation or crop rotations would be dangerous to the soil. While not strictly comparable with the shade system of coffee, it has points of resemblance in the complete and continuous cover of the soil it provides and the stratification of the vegetation on the land.

CACAO DISEASE IN BRAZIL

In a private communication, P. Silva and W. T. Lellis of the Cacao Institute of Bahia, Brazil, report that the following are the more important diseases of cacao observed to date in Brazil: brown pod rot (*Phytophthora palmivora* Butler), die back or black pod rot (*Diplodia theobromae* Nowell), red rust or algal disease (*Cephaleuros mycoidea* Karst.) and pink disease *Corticium salmonicolor* B. and Br.). Numerous other diseases of relatively minor importance have also been recorded.

Brown pod rot causes considerable reduction in the yield of cacao. Experiments in Bahia have shown that spraying with Bordeaux mixture can be applied economically where losses exceed 15 per cent. of the crop. In certain years black pod rot is as serious as brown pod rot, and the same pathogen causing black pod rot is also responsible for die back of the twigs. Red rust or algal disease is prevalent in unshaded cacao. This disease can be controlled by removal of affected twigs, application of Bordeaux mixture and increasing the overhead shade.

A disease, erroneously referred to as grey disease, was reported recently in Bahia. This is not a new disease. The incorrect name resulted from the faulty translation of the words "padridao parda", which mean brown rot, in a paper by Dr. Sosthenes Miranda dealing with the well-known brown pod rot of cacao.

CONTROL OF PIANO GRASS

BY

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Themeda arguens (L.) Hack., locally known as Christmas or Piano grass, a native of Asia, was introduced into Jamaica probably about twenty years ago. Its spread was at first slow and it did not become the object of notice until about ten years ago when it had invaded extensive localised areas of the pastures in the parishes of Trelawny and St. Thomas. Since then it has occupied large and widespread areas in these parishes and is now rapidly invading new districts.

It is an objectionable pasture weed on account of the awns borne on the fruit. As the fruits mature these awns become stiff and very wiry and lodge in the nostrils and eyes of grazing cattle causing irritation of the mucous membranes often leading to suppurative sores. The areas in which Piano grass principally occurs are dry and unsuitable for regular arable cultivation. The possibility of control by rotational cropping is, therefore, unpromising. The nett monetary return from the cattle in these areas is low and penkeepers (cattle farmers) were unwilling to consider any control measures likely to involve appreciable expenditure. The only control measure which had been tried in practice and adopted by a few farmers was firing the pastures before the fruit was dispersed. Apart from the resultant loss of existing fodder this procedure is to be condemned as flowering usually occurred just before the onset of a dry season with the result that the pastures take a considerable time to recover. A few fields in the Piano grass area were ploughed during the war for food production and it was evident that the grass could be so controlled, but unless adjacent areas were also dealt with the cultivated area became rapidly reinfested. The grass flowers once annually, around November, and the fruits mature from mid-December to February. The obvious remedy of mowing or cutlassing early in December resulted in a new though weaker flush of flowering which in some fields necessitated repeating the process four to six weeks later. This recommendation was rejected by farmers as being too costly.

The problems that presented themselves were therefore three :—

1. To devise a means of destroying new infestations in unaffected areas.

2. To replace large acreages of Piano grass with a less objectionable species at low cost.

3. To find such a species which would not subsequently be replaced naturally by Piano grass.

In the first place an attempt was made to devise a herbicidal treatment using readily accessible and inexpensive materials. In 1941 a small randomised plot experiment using 1/40 acre plots separated by 3 ft. intervals was laid down on a pure stand of Piano grass. Treatments were replicated five times and included spraying with solutions of copper sulphate, sodium chloride, light gas oil at the rate of 4 cwt. per acre, application of lime at the rate of 10 tons per acre, using *Edua pea* (*Macuna* sp.) as a smother crop, cutting at six weekly intervals, bare fallow, and cutting annually soon after flowering. None of these treatments were effective in destroying the grass permanently. The sprays used, even after three successive applications, failed to destroy the roots and though the foliage was killed the grass rapidly regenerated. Further applications would have rendered the cost excessive. Repeated cutting did not destroy the plants, and the smother crop only did so partially. Fallowing, ploughing followed by a succession of harrowings, was effective but continuous reinfestation occurred, and this method would only be satisfactory in new outbreaks.

The possibility of biological control by a more vigorous grass was then considered. The grasses used were :—

Molasses grass	*Melinis minutiflora* Beauv.
Bermuda grass	*Cynodon dactylon* (L.) Pers.
Guatemala grass	*Tripsacum laxum* Nash.
Blue Panic	*Panicum coloratum* L.
Swaziland Finger grass	*Digitaria swazilandensis* Stent.
Elephant grass	*Pennisetum purpureum* Schum.
Guinea grass	*Panicum maximum* Jacq.
Rhodes grass	*Chloris gayana* Kunth.
Seymour grass	*Andropogon pertusus* (L.) Willd.

and "Amphilophis" a variety of *Andropogon pertusus* introduced into Jamaica under the binomial *Amphilophis pertusus*. Of these, seven are creeping species spreading by runners, rhizomes or stolons, and three, Guatemala, Guinea and Elephant, stooling species, in connection with which it was of interest to determine whether they would prove resistant to encroachment by Piano grass.

The same site used for the original experiment was again used and any possible residual effects of the previous treatments were avoided as far as possible by distributing the four replications of each of the new treatments over four of the old ones. The results of the present experiment show that this method was satisfactory in avoiding such effects.

Each plot, 33 ft. square, already established in Piano grass was divided into three strips 33 ft. x 11 ft. Piano grass was removed from the middle strip and the experimental grass planted, watered when necessary and weeded until a pure stand had covered the strip and joined up with the Piano grass on each side. Thereafter, no preferential treatment was given to the experimental grass and free competition with the Piano grass along the 66 ft. of junction took place. The plots, which in the previous experiment had been bare fallowed, not being established in Piano grass, were completely planted with the experimental grass mainly to determine the possibility of invasion by Piano grass by seeding; at the same time these plots were in vegetative competition with the Piano grass in the interplot intervals along the whole of their outside edge, 132 feet. With each experimental grass the strip technique was therefore repeated three times and the whole plot occurred once. Fig. 1 illustrates a portion of the layout. The plots were billed to within about four inches of the ground at approximate intervals of six weeks to simulate the effects of light grazing. Observations on the progress of the experiment were kept by making plans to scale of all the plots at three-month intervals and from these the area occupied by each grass was determined.

Owing to erosion of one grass by another and to differences in growth rate of the various grasses at different seasons the line of demarcation was often ill defined and for purposes of record was arbitrarily mapped separating areas in which the two grasses concerned were dominant. The error of estimation so introduced was of course variable but is considered in no case to be more than plus minus 10% and is generally less. The final observation was made when the Piano grass was tall and in full flower and the area of experimental grass is likely, therefore, to be underestimated.

Planting of the experimental grasses was commenced in July, 1943, but owing to continued dry weather the plots were not properly established until April, 1945, from which time the experiment was considered to have started. On two occasions cattle broke into the field and grazed it overnight but no marked evidence of differential grazing was observed and no serious damage to the experiment resulted.

Observations were commenced in January, 1946, as soon as signs of encroachment of one grass by another had become apparent and were continued until January, 1947. Thereafter, the plots were thrown open to light grazing to determine the preferences of the cattle for the various grasses used. This phase of the experiment is still in progress.

The original observations are summarised in Table I, which gives the mean percentage change in area of the experimental grass for the three plots divided into strips, resulting from competition with Piano grass. The data are graphically represented in Fig. 2.

It is clear that Bahama, Molasses, Rhodes and Guinea grass were quite unable to compete with Piano grass. The Guinea grass stools were planted approximate 2 feet apart and the foliage provided insufficient shade to prevent colonisation by Piano grass between the stools, thereafter presumably as a result of root competition, the Guinea grass stools were steadily killed out. Rhodes grass was evidently unsuited to the environment; growth was feeble from the start and in addition to the Piano grass, Bahama and Seymour grasses as well as the Composit *Wedelia trilobata* rapidly invaded the plots, and seedlings of Amphilophis and Molasses grass became established. Though Molasses grass proved an inefficient vegetative competitor with both Piano and Seymour grass, Molasses grass seedlings succeeded in establishing themselves sporadically but temporarily in the adjacent Piano grass and Rhodes grass plots.

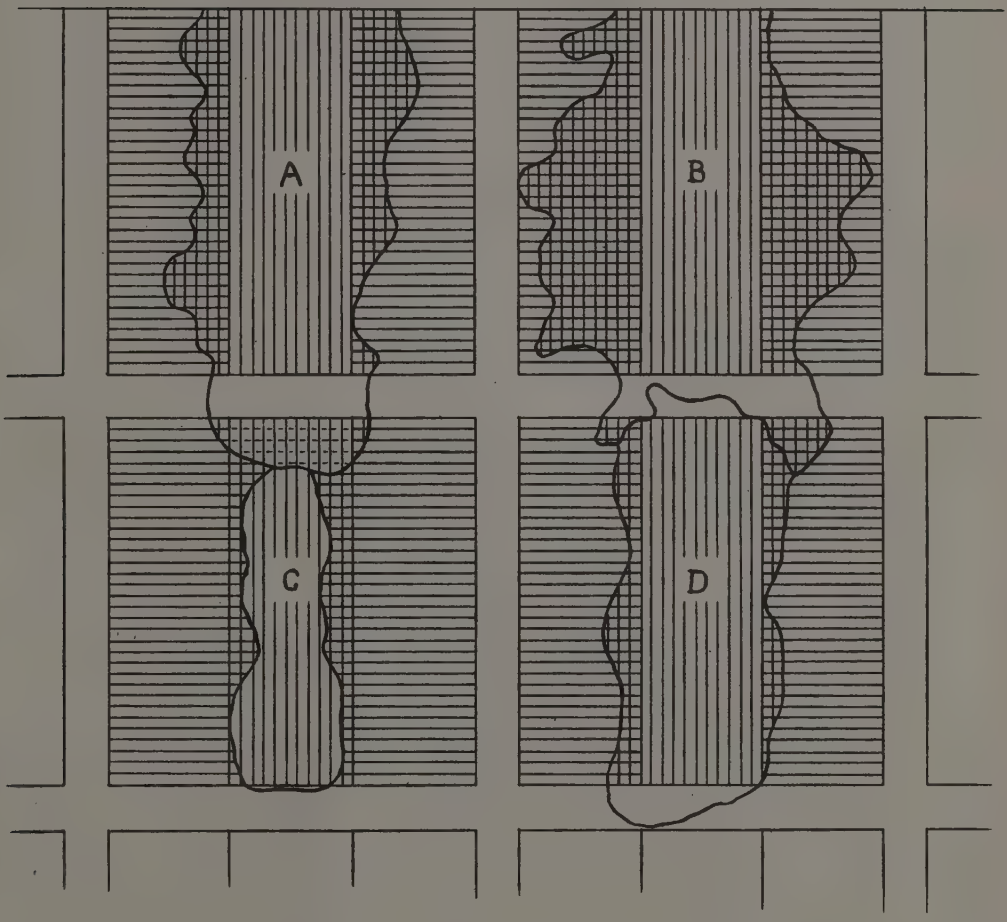
TABLE I

PERCENTAGE CHANGE IN AREA

Grass	DAYS				
	0	283	398	538	653
Bahama	0	—71.1	—55.3	—79.8	—95.5
Guatemala	0	0	0	— 0.8	(—24.8)
Seymour	0	+30.1	+45.4	+65.0	+51.8
Amphilophis	0	+20.1	+39.9	+58.4	+41.6
Molasses	0	—30.1	—68.3	—91.4	—99.1
Blue Panic	0	+11.3	+17.1	+ 7.3	—67.7
Finger	0	+19.6	+38.3	+46.6	+43.8
Elephant	0	0	0	+ 1.9	(— 8.8)
Rhodes	0	—50.4	—93.4	—98.3	—100.0
Guinea	0	—38.8	—30.3	—36.1	— 97.2

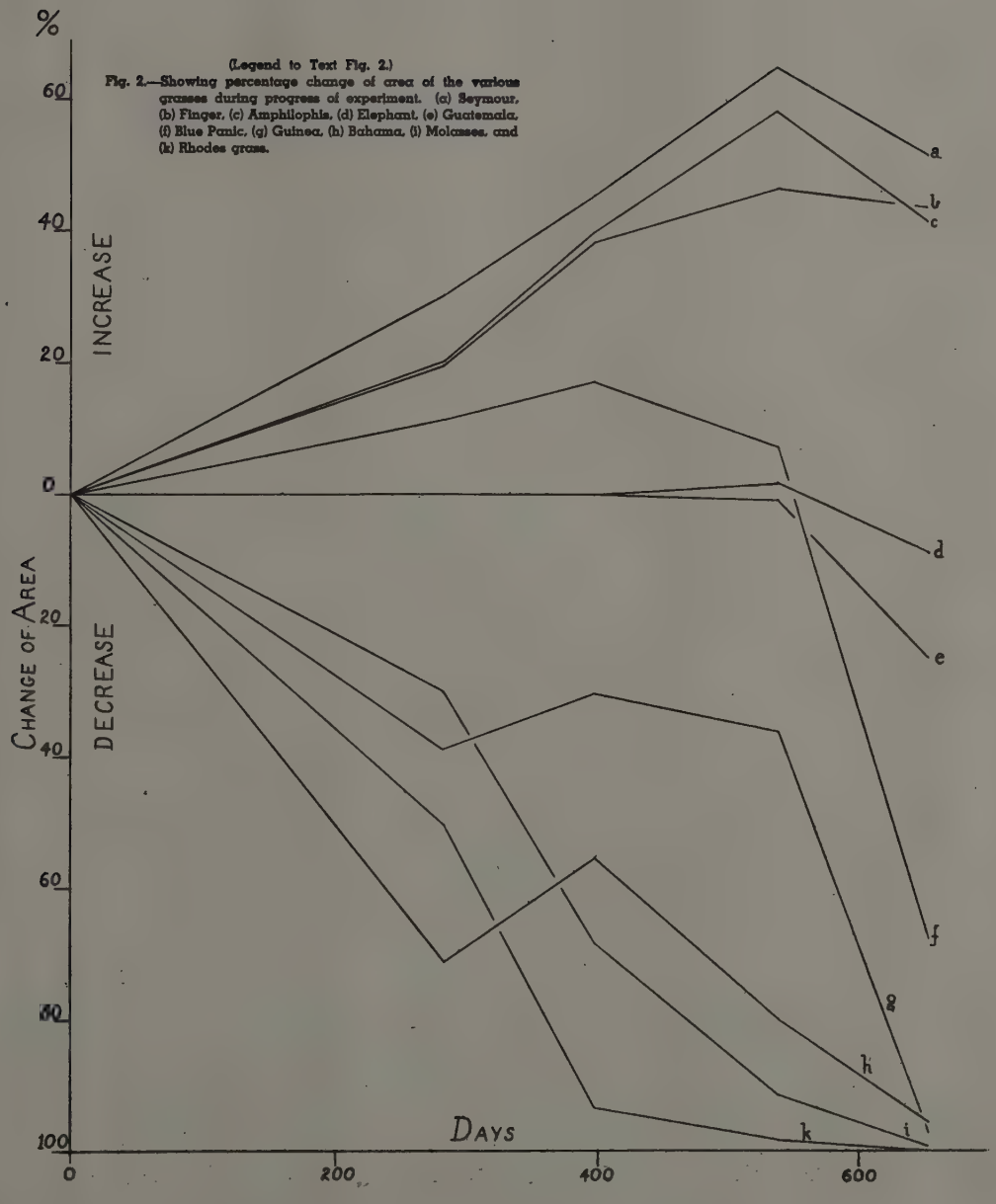
(Legend to Text Fig. 1.)

Fig. 1.—Portion of layout after 538 days showing four plots. Vertical shading — experimental grass. Horizontal shading — Piano grass. Cross hatching — area of encroachment by (A) Seymour grass, (B) Amphilophis, (D) Finger grass, into Piano grass and by Piano grass and Seymour grass into Guinea grass (C). Scale 1/20 inch = 1 ft.



(Legend to Text Fig. 2.)

Fig. 2.—Showing percentage change of area of the various grasses during progress of experiment. (a) Seymour, (b) Finger, (c) Amphilophis, (d) Elephant, (e) Guatemala, (f) Blue Panic, (g) Guinea, (h) Bahama, (i) Molasses, and (k) Rhodes grass.



On the other hand Guinea grass seedlings appeared in the Molasses grass but were subsequently killed out by Piano grass. As may be seen from the table Bahama grass was successful at times in growing into Piano grass but in the end the Piano grass proved more aggressive. Bahama grass cover was insufficiently thick to prevent Piano and Seymour grass seedlings coming up through it. Furthermore, both *Wedelia trilobata* and Seymour grass were successful vegetative invaders of Bahama.

The two other tufted species, Guatemala and Elephant grass gave a sufficiently dense cover to prevent infiltration of Piano grass. The encroachment of Piano grass indicated in brackets in the last column of Table 1 is not significant as the stools on the edges of the plots of these grasses had been weakened as a result of taking samples for analysis and cutting planting material. Both these species resisted Piano grass invasion but showed no signs of spreading into the Piano grass.

Blue Panic grass showed signs of competing successfully with Piano grass in the early stages of the experiment but later was largely killed out. This suggests that under environmental conditions more favourable to its growth it might prove a successful competitor. It is probable that its failure in this instance was due to the effects of drought. Where this grass came into contact with Seymour grass the latter proved the more efficient grower and encroached into the Panic grass.

The most successful competitors with Piano grass were Amphilophis, Seymour and Finger grasses and of these the two first were probably slightly better than the last though this gave the thickest mat. Amphilophis gave a heavier growth of herbage than Seymour which in turn established itself more readily than Amphilophis in plots of the other grasses used. Amphilophis and Seymour possess the additional advantage of seeding freely and the seedlings were able to established themselves in plots of most of the other creeping grasses used in the experiment, including Piano grass. The progress of vegetative encroachment of these three grasses for the duration of the experiment approximates to a linear function with a rate of about 50% increase in 20 months. Theoretically this function should be curvilinear but as the rate of spread is not uniform in different parts of one plot the junction of the competing grasses becomes irregular with the result that the rate of increase of area approximates more closely to the rate of increase of perimeter than would be expected: the limiting cases of the rate of increase of area being a circular function of the increase of perimeter, and zero. Under average growth conditions it is, therefore, to be expected that the area would be doubled in just over three years. With the additional stimulus of seedling encroachment this period would probably be reduced.

It is apparent, therefore, that Piano grass can be killed and supplanted by biological competition with a more vigorous grass under the conditions of the experiment. Since the last observations of change of area were made in January, 1947, the plots have been subjected to light grazing for a period of three months. During this period the Piano grass has been in flower and fruit and has given very little bite and the experimental grasses have therefore been more severely grazed. It is proposd to continue light grazing until a new flush of growth of Piano grass has appeared and then, with less inducement to selective grazing, the plots will be thrown open to the rest of the field and subjected to the same grazing conditions as the surrounding Piano grass.

The effect of the preliminary phase of light grazing has been almost total destruction of the Amphilophis. This grass has evidently proved particularly palatable to the cattle as it has been grazed to the ground and in addition has apparently a poor root hold as most of the stools have been eradicated in the process of grazing. Both Seymour grass and Finger grass have stood up well to grazing and growth of these has not been set back. It now remains to be determined whether the same results will obtain under conditions of normal grazing. If this is so it should prove possible to replace Piano grass by either Seymour or Finger grass by planting and establishing strips of these grasses through the area and leaving nature to do the rest. Though this process is likely to be the least expensive method of controlling Piano grass its progress would be slow. Theoretically it should take 15 years to eradicate the Piano grass from a 16-acre field by planting strips totalling ½ acre in area. The intervention of environmental hazards, such as drought proving relatively detrimental to growth of the controlling grass, might prolong this period considerably. The palatability of Amphilophis and Finger grass has only been preliminarily investigated and should these be preferred by cattle to Piano grass under normal grazing conditions their use would prove more costly if not impracticable as fencing and possibly laying up the pasture for extended periods would be necessary. The preliminary conclusion is that this is likely to be the case with Amphilophis but not with Finger grass. Observation on patches of Seymour grass established in Piano grass pastures indicates that cattle show no marked preference for either of these species.

The relative nutritional value of these grasses requires further investigation. Analyses of a few samples have already been carried out and suggest that the nutritive value of Piano grass is as good if not slightly better than the other three grasses under discussion. Amphilophis in particular tends to be more fibrous and contains less protein; its preference by cattle is therefore rather surprising. None of the four grasses under discussion approached either Elephant or Guatemala grass in nutritional value. It is apparent, however, from the few samples analysed that the variability of nutritional status of any one species from time to time is very great and the result of further analyses must be awaited before any final conclusions on this aspect of the problem can be made.

So far as information is at present available there can be no doubt that the best method of destroying a new infestation by Piano grass in hitherto unaffected areas is by digging it out and burning or by digging it in and tilling. In areas where extensive infestation has already occurred damage to cattle can best be minimised by mowing in December while the grass is still in flower and before the seed is mature; if necessary a second mowing should be carried out four to six weeks later if a new flush of flowering occurs. In small areas where mechanical mowing equipment is not available billing or cutlassing can be substituted. The replacement of Piano grass in large areas by a less noxious species calls for a more protracted programme lasting a decade or more. Seymour and Finger grasses offer most promise for this purpose with Seymour most likely to produce the quickest results.

It is evident that the ecological balance between the various grasses used is delicate and a slight change in environmental conditions such as could be produced culturally may reverse the effect of mutual competition. This is apparent in parts of the parish of St. Andrew where Piano grass is actively encroaching into areas at present dominantly occupied by Seymour grass, the reverse procedure to that prevailing under the conditions of the experiment. The results and conclusions are therefore only strictly applicable to the area of the parish of Trelawny where the experiments were conducted and should be applied elsewhere on an experimental scale in the first place. This situation also suggests that the competitive margin may be effectively increased by artificial modification of the environment and further experimentation to find differential effects of modified management such as the use of fertilizers, or the system of grazing, is indicated.

Summary

Themeda arguens (L.) Hack., known locally as Piano or Christmas grass, has proved a troublesome pasture weed and injurious to grazing cattle. Experiments aimed at its control are described. Economic considerations render the use of herbicides impracticable and climatic considerations preclude rotational cropping.

Biological control by competitive grasses is attempted and experimental results suggest that Amphilophis and Seymour grass, which are both varieties of *Andropogon pertusus* (L.) Willd., and Finger grass, *Digitaria swazilandensis* Stent., may prove effective over an extended period. Bahama, Molasses, Blue Panic, Rhodes, Guatemala, Guinea and Elephant grasses proved unsuitable for the purpose.

Further investigation into the palatability and nutritional value of the suggested competitors is indicated.

PESTS AND DISEASES OF CACAO IN TRINIDAD

Diseases of cacao in Trinidad include a number caused by fungi, of which *Marasmius perniciosus* Stahel is the most important, and virus diseases. Transmission experiments have shown that the latter are caused by two strains, designated red mottle virus and vein clearing virus. The symptoms have been found in both weak trees and those that were otherwise normal and vigorous, in a limited area at the western end of the Northern Range in Trinidad. There is no indication of a reduction in yield as a result of virus infection, and the vectors are not known.

The more important insects that attack cacao in Trinidad include *Selenothrips rubrocinctus* Giard, which feeds on the foliage, causing staining and russeting of the leaves. Severe infestation usually results in heavy leaf-fall, followed by the production of new foliage and the withering and death of all pods developing at the time. Repeated attacks of this nature result in severe die-back of the tree, which may be killed in extreme cases. The nymphs are considered to be more injurious than the adults. It is believed that the liability to mass attack by thrips is connected with the physiological condition of the tree, but the connection is obscure. Severe outbreaks can be prevented or controlled by spraying with Bordeaux mixture or milk of lime or by dusting with hydrated lime. The introduced parasite, *Dasyscapus parvipennis* Gahan, has survived in several localities in Trinidad and extended its range in some of them, but it does not appear to be exerting useful control.

The larvae of *Steirastoma depressum* L. tunnel in the young branches, especially at the base, or at the collar of the trunk of young trees, causing serious local injury and frequently complete ringing of the affected branch. The adults feed on the bark ; this injury is usually superficial, but may be deep enough to cause partial or total ringing. Young trees in vigorous growth and newly trimmed trees are particularly subject to attack. This beetle breeds throughout the year, but its numbers increase most rapidly during the dry season. Natural enemies include insectivorous birds, Elaterid larvae and several Braconid parasites, but it is doubtful whether they effect appreciable control.

Attacks by *Howardia biclavis* Comst. and *Asterolecanium pustulans* Ckll. first recorded in 1941 have so far all been confined to young cuttings of selected material. These suffer severe damage when newly planted in the field, and usually die within a few weeks, unless the infestation is promptly checked. A spray of resin wash appears to give reasonably good control. Other Coccids, of occasional and minor importance, include *Pseudococcus citri* Risso, *Ferrisia virgata* Ckll., *Selenaspidus articulatus* Morg., and *Aspidiotus destructor* Sign., some of which may prove to be vectors of the virus diseases.

(Rev. Appl. Ent. A, 35 : 88—89, 1947).

PEASANT AGRICULTURE IN THE LEEWARD AND WINDWARD ISLANDS

Part I.—The Development of Peasant Agriculture

BY

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[The following article is the first part of a report submitted to the Secretary of State for the Colonies.]

Historical Introduction *

The present survey is confined to the Leeward and Windward Islands which form part of the chain of islands stretching from the peninsula of Florida to the mainland of South America. The islands differ so widely in their history, soils, climates and crops as to render generalisation difficult and dangerous. They do share, however, certain associations and characteristics which have an important bearing on problems of peasant agriculture. The present introduction is intended to provide a background for the more detailed discussion of peasant agriculture which follows. The Leeward Islands were settled by the British early in the seventeenth century and have since remained almost continuously in British possession.† The Windward Islands, by contrast, were acquired by conquest from the French during the second half of the eighteenth century.

The Leeward Islands The first settlers in the Leeward Islands were small-holders‡ who themselves cultivated tobacco, cotton and indigo with the aid of a few white labourers.§ The reign of the small-holders was short-lived, for the introduction of "modern sugar works" was revolutionary in its economic and social consequences.¶ European labourers proved incapable of performing the heavy manual tasks involved in cultivating and reaping sugar cane, and in manufacturing sugar; and the Caribs, scanty in number but warlike in character, found sanctuary in the fastnesses of the undeveloped Windwards. It was soon discovered that negro slaves could perform both field and factory work efficiently under the supervision of a few white overseers. The Dutch (and afterwards the English Royal) African Company were only too anxious to supply slaves, and, within a few years, slaves greatly outnumbered the rest of the population. Thus, the long reign of "King Sugar" commenced at an early stage in the development of the Leeward Islands.

The purchase of slaves and animals and the erection of sugar works necessitated expenditure on a scale beyond the resources of most of the existing small-holders. The small-holders led a precarious existence by reason of the heavy import duties which Great Britain imposed on their products, and the wealthier sugar planters seized every opportunity to buy out their less favoured neighbours. The land soon passed into the hands of a small number of magnates who rapidly amassed great fortunes. In this manner the plantation became the characteristic unit of agricultural production in the Leeward Islands.

The Old Colonial System The British West Indies have declined so much in importance, relative to other parts of the British Empire, that it is difficult for the twentieth century observer to appreciate that during the seventeenth and eighteenth centuries these islands were the most highly prized of British overseas possessions. The aim of the "Old Colonial Policy" was a strong self-sufficing empire. Colonies were acquired to achieve this end, and their trade was strictly regulated within the framework of three momentous Acts of Parliament—the Navigation Act (1660), the Staple Act (1663) and the Plantation Act (1673). These Acts gave the West Indian Colonies a virtual monopoly of the expanding English sugar market, and made England, at one time, an entrepot for the European sugar market. The "sugar colonies", as the British West Indies were termed, constituted a valuable market for tools, clothing and provisions, and none of their industries competed with those of England. The islands provided a profitable market for the West African trading posts and employed large numbers of British ships and seamen. The employment of slaves reduced the drain on the man-power of the Mother Country. The West Indies furnished strategic bases from which attacks could be launched on foreign trade and colonies in the New World. They were complementary to the Mother Country in almost all respects and conformed most closely to her ideal of a strong self-sufficing Empire. Their long coastlines and numerous roadsteads and harbours brought every plantation within easy reach of a shipping point and permitted the West Indies to become a classic example of an exchange economy long before the steamship and railway brought the hinterlands of the great African continent within the orbit of world trade. The old empire was overweighted on the temperate side, and the West Indies remained the "pampered pets" of the British Empire throughout the seventeenth and eighteenth centuries.

* For fuller accounts see (12), (13) and (14).

† St. Kitts was shared for a time by British and French settlers and the Leeward Islands were overrun by the French in 1662.

‡ In St. Kitts, 243 (out of a total of 438) British settlers who "lost their estates" when the French captured the island in 1666 had held a total of 4108 acres of land, or an average of 17 acres each. See (8).

§ The first settlers in St. Kitts enslaved a few of the Carib inhabitants, but this supply of labour failed almost at once because the Indians soon died off in slavery. White indentured servants were recruited from three sources: (i) Voluntary emigrants who bound themselves to serve a number of years in return for their passage and a bounty, (ii) malefactors released from prison on condition that they served in the colonies as indentured servants, and (iii) political prisoners shipped off in virtual slavery. See (8).

¶ The first "modern sugar works" were introduced into Barbados from Brazil in 1642.

System of Agriculture Sugar production, under the Old Colonial System, remained so highly profitable in the British West Indies that the system of agriculture introduced by the pioneer planters became stereotyped. These pioneers had naturally adapted to West Indian conditions the system of agriculture then current in England, namely, a division of the land into arable and pasture areas, the cultivation of the land in the same* crop year after year, with occasional periods of fallow, and with the periodic application of dung. The revolutionary principles of rotational farming and alternate husbandry which were adopted in Europe during the late seventeenth and early eighteenth centuries had no repercussion in the British West Indies, for sugar was so profitable as to convince planters that the introduction of any rival crop would reduce their profits (18).

Neither the aborigines nor the negroes made any important contribution to West Indian agricultural practices. Such of the Caribs as survived the many conflicts with European settlers were gradually merged by miscegenation into the general population. The slaves were brought from West Africa to the West Indies to serve as labourers on the plantations, and, although they grew some of their food, they soon lost their tradition of self-sufficiency. Thus, the British West Indies differ from the African dependencies, Malaya, Ceylon, Fiji and other parts of the British tropics where there remain large indigenous populations with a tradition of self-sufficiency in food production.

The Windward Islands Grenada, St. Vincent and Dominica were added to the British Empire by the Treaty of Paris (1763). Grenada was the only one of these islands to have been regularly colonised and exploited by France.† Dominica and St. Vincent were relatively undeveloped because their ownership had long been disputed between Great Britain and France, and they (together with St. Lucia) had been regarded as neutral and reserved for Carib occupation after the Treaty of Aix La Chapelle (1748). Only a small number of French planters had ventured to contravene this understanding by settling in Dominica and St. Vincent prior to 1763.

Sugar planters in the older British islands had opposed the retention of the French islands for fear of a fall in the monopolistic prices they then enjoyed in the English sugar market, but immediately the islands became British, planters from the Leewards hastened to buy cheap virgin land in the Windward.s‡ The development of the newly acquired Windward Islands was primarily in sugar and was accompanied, characteristically, by the squeezing out of smallholders. St. Lucia was added to the present Windward group in 1803. The Windward Islands were only partially exploited when the abolition of the slave trade in 1807 prevented the purchase of additional slaves, and they were less than half as thickly populated with slaves as the Leewards at the final registration in 1832.

Emancipation When the Act of Emancipation in 1838 conferred on the bulk of the population the civil status entitling them to acquire land, there were still large areas of Crown, or unalienated, land in the Windwards but none in the Leewards. But no attempt was made to develop peasant farming in the Windward Islands after Emancipation; on the contrary, the policy of the British Government was to make it difficult for labourers to acquire small holdings in order that they would be compelled to work regularly for wages and thereby assist to maintain the staple industry, sugar (7). In any event, there was little except provisions which smallholders could have grown at this time, because the planters were unwilling to buy sugar cane for fear of dislocating their labour supply, and export crops such as indigo and cacao, which required little capital equipment, were subjected to such heavy duties by Great Britain as to render their production highly speculative (6).

Free Trade But Free Trade followed hard on the heels of Emancipation. Great Britain was rapidly becoming the workshop of the world and the fetters of the Old Colonial System were hindering her search for raw materials and markets (9). The reversal of British tariff policy had important repercussions in the West Indies. The Equalisation Act of 1846 swept away the prohibitive and discriminating duty which had hitherto been levied on foreign sugar entering the United Kingdom, and thus exposed the West Indian wage-paying sugar planter to the competition of foreign slave-grown sugar. Many marginal sugar estates in the British West Indies were forced into bankruptcy and a few were sold out in small-holdings. In contrast with sugar, the production of minor crops became highly profitable: for reductions in import duties, combined with increases in real wages in the United Kingdom, permitted a rapidly increasing population to multiply its demand for luxuries. The planters of Grenada hastened to convert their estates from sugar to cacao, and the labourers who were employed as "contractors" to effect this transition acquired sufficient capital for the purchase of small-holdings. Thus, the death of the sugar industry and the birth of the cacao industry in Grenada afforded labourers their first widespread opportunity to become peasant proprietors. The sugar industry survived in the other islands but the planters in Nevis, Montserrat and St. Lucia, finding themselves unable to pay wages in cash, resorted to the share-cropping system. A rapid expansion in the consumption of sugar in the United Kingdom eventually brought some relief to the West Indian planters, but the recovery was short-lived: for bounty-aided beet sugar soon afterwards flooded the market, and by 1896 the West Indian sugar industry was on the verge of collapse.

* Similar crops were grown in succession in England.

† Grenada, in 1763, contained 81 sugar plantations, 208 raising coffee, cacao or stock while 21 estates were lying abandoned. See (10).

‡ Land sold by auction realised per acre an average of less than £8 in St. Vincent, and less than £3. 10. 0. in Dominica. Good land in St. Christopher was said to have been sold at £100 per acre about this time (this land was probably in cultivation and the price may have included buildings, etc.) See (10).

Land Settlement The Governments of the Leeward and Windward Islands had hitherto done little or nothing to encourage peasant farming; but the West India Royal Commission of 1897 recommended that they "should exert themselves in the direction of facilitating the settlement of the labouring population on the land" (2). "It seems to us that no reform affords so good a prospect for the permanent welfare in the future of the West Indies as the settlement of the labouring population on the land as small peasant proprietors; and in many places this is the only means by which the population can in future be supported..... We see no objection to the system of large estates when they can be maintained under natural economic conditions. On the contrary, we are convinced that in many places they afford the best and, sometimes, the only profitable means of cultivating certain products, and that it is not impossible for the two systems of large estates and peasant holdings to exist side by side with mutual advantage" (2).

All the land in the Leeward Islands and the best agricultural land in the Windward Islands had already been alienated. The Commission did not hesitate, however, to recommend the compulsory acquisition of land for settlement purposes provided it had "practically ceased to be cultivated" (2).

The report of the 1897 Commission may be regarded as the Magna Charta of the West Indian peasant. The Government of St. Vincent immediately (1899) embarked on an extensive land settlement scheme and Carriacou followed in 1903, but several years elapsed before any other Government implemented the recommendation of the Commission and it was not until 1916 that Antigua became the first of the Leeward Islands to inaugurate a Government land settlement (4).

The West Indian Sugar Commission of 1929/30 expressed its conviction that "the increased settlement of labourers on the land as peasant proprietors offers the best prospect of establishing a stable and prosperous economy in the West Indian Colonies" and regretted that "so little has been done to carry out the strong recommendations of the 1897 Commission in this direction" (5). Land settlement schemes were inaugurated in Dominica, Nevis and Anguilla, and extended in other islands, during the 1930's. The Royal Commission of 1938/9 pointed out that land settlement "is only one of several ways by which the number..... of peasant holdings may be increased" and recommended "that the order of procedure should be, first, the improvement of the husbandry of existing small-holders, in the light of the results of some of the enquires recommended.....; then, the improvement of existing land settlements and the establishment of new settlements".

Thus it was not until the very end of the nineteenth century that the State actively encouraged the development of small-holdings. It is true that there were a few small-holders—European, free people of colour,* and manumitted slaves—before Emancipation; but neither they nor the runaway slave squatters received encouragement from either the British Government or the local "plantocracies," and their numbers remained insignificant. But the incapacity of the slaves to own or rent land did not mean that they were prohibited from cultivating the soil on their own account—on the contrary, the great majority of them were provided with gardens or provision grounds on the estates. The recurrent crises in the sugar industry during the nineteenth century afforded opportunities for agricultural labourers and others, to become share-croppers, cash tenants and even peasant proprietors. Some became squatters in the wilds of Dominica and St. Lucia. The varied circumstances in which these peasants acquired the use of land are described in the following chapters.

* Free coloured persons in St. Vincent were apparently debarred from becoming freeholders. See (11), Slave Act, 16/12/1825.

Labourers' Provision Grounds

Slaves' Provision Grounds The slave owner's paramount interest lay in the production of an export crop; and to it all suitable land was devoted. But many plantations embraced land which was too steep, inaccessible or infertile for cultivation in the staple crop. Moreover, the labour requirements of sugar—with which the great majority of the planters were concerned—exhibited marked seasonal variations. Indeed, planters complained of the difficulty of finding full-time profitable occupation out of crop for the number of slaves they required during crop. The planters were responsible for housing and feeding their slaves, and they realised that by allocating a small plot of land to each family for the purpose of growing food crops they could reduce their expenditure on rations. The amount of land allocated to the slaves varied from plantation to plantation and from island to island. In Antigua, for example, most of the land could be cultivated in sugar-cane, and this island became typical of what were termed the "foreign-fed" colonies. In St. Vincent, by contrast, the slaves were afforded abundant land for growing food and raising small livestock. The more fortunate and industrious slaves in the Leeward and Windward Islands produced provisions in excess of their family requirements and disposed of the surplus for cash at the Sunday market. The allocation of a garden or provision ground and the grant of an appropriate number of holidays to enable the slave to cultivate the land were first governed by customs, but were later secured by law. None of the slaves, however, was entirely self-supporting in respect of food, and the planter invariably supplied some rations, such as salt-fish.

Labourers' Provision Grounds The conditions regulating the allocation and cultivation of estate gardens and provision grounds were altered by the Act of Emancipation. The planter was thereby relieved of the obligation to provide his labourers with rations, housing and provision grounds; but he could no longer compel them either to work as and when required, or to remain in his employment. He

endeavoured to retain a large and elastic supply of labour by offering labourers task work and the perquisite of a plot of land. The labourer could be deprived of his provision ground if he failed to work to the satisfaction of his employer. Thus, the use of a provision ground, which had been secured to the slave by law, now became subject to the arbitrary decision of the employer. The labourer had no legal security of tenure and was not entitled to compensation on eviction.

This linking of wage earning with the use of land persists to this day, but it does not provide a sound basis for peasant agriculture. There is little encouragement for the labourer to cultivate in an husbandlike manner, or to effect improvements of a capital nature, because there is no guarantee that he will either retain possession until he has reaped their full benefit, or receive compensation for their unexhausted value. The right to dispossess a labourer of his provision ground is a disciplinary weapon which the planter cannot afford to wield indiscriminately and many labouring families have remained in undisturbed possession of their provision grounds for several generations. Planters in general are not deeply concerned to ensure the maintenance of fertility of land from which they derive no revenue. Labourers on estates which embrace abundant 'mountain land' have practised a system of shifting cultivation by which much protective forest has been destroyed, but some planters are now taking measures to prevent such indiscriminate destruction.

There is no record available of the numbers, area or production of such provision grounds. Many planters affirmed, just prior to the present war, that labourers were less inclined than formerly to make adequate use of provision grounds.

Share Cropping

Share-cropping is widespread in both Montserrat and Nevis and exists on a smaller scale elsewhere in the Leeward and Windward Islands. One-third the land registered (in 1940) as under cotton in Montserrat was cultivated by share-croppers.* Nearly all the land cultivated in Nevis is worked either by peasant proprietors or by share-croppers and only one estate has a pay roll of any consequence (15).

The present share-cropping systems do not provide a satisfactory basis for peasant agriculture in the Leeward and Windward Islands. Share-tenancy, in contrast to share-cropping, is a system of land tenure of distinctive merit, and one which is growing in popularity in Canada and the United States of America; but there is no prospect of introducing share-tenancy into Montserrat and Nevis because the landowners lack the necessary capital. The present account of share-cropping in these two islands is therefore inevitably confined to a demonstration of the defects of the system.

* In 1934 share-croppers cultivated 48% of the land under cotton but the area they occupied, 1,508 acres, was actually a little less than in 1940 when they cultivated 1,564 acres. See (17).

Montserrat

Historical Outline The nature of share-cropping is clearly revealed in its history. The system in Montserrat appears to have originated about 1847 when a widespread financial crisis deprived the sugar planters of the credit upon which they had depended for paying wages. The sugar planters divided their fields into small plots which were allocated to labourers who grew sugar-cane and shared the proceeds with the planters. This expedient provided the labourers with a means of livelihood, and enabled the planters to continue as sugar producers despite the lack of credit. But when the price of sugar subsequently recovered to a profitable level, and credit again became available, the planters resumed the cultivation of their estates with wage-paid labour.

Half a century later, when the British West Indian sugar industry suffered another depression, the planters of Montserrat followed the example of their predecessors by resorting to the share-cropping system. This depression proved fatal to the sugar industry of Montserrat; but the re-introduction of cotton provided the planters with a profitable crop and enabled them to revert to wage payments. By 1910, share-croppers were confined to 200 acres of cotton, representing only 10% of the land under that crop. The planters of Montserrat appear to have experienced no difficulty up to this time in persuading wage labourers to become share-croppers during periods of depression, and share-croppers to become wage labourers during periods of prosperity.

The rise in the price of sugar following the outbreak of war in 1914 led to a flickering revival of the industry in Montserrat. Labourers were attracted to the sugar estates by the offer of land on a share-cropping basis and the prospect of benefitting directly from high sugar prices. Cotton planters were also anxious to make the most of high prices and they, too, offered land on a share basis. Thus, for apparently the first time, share-croppers increased in number during prosperity, while the area cultivated by planters, instead of expanding rapidly, remained almost stationary. At the height of the boom in 1919 share-croppers cultivated 968 acres of cotton, or 30% of the total area under that crop.

Special arrangements were made to enable producers to dispose of their cotton, or to obtain credit, throughout the post-war depression, and by 1929, when the price had risen, the area under cotton had reached a record of 4,000 acres. Three years later, the price of cotton had fallen by 50%, and by 1933 the acreage under estate cotton had dwindled to 104 acres, or 5% of the total cotton acreage. Share-croppers, by contrast, increased their area under cotton from 932 acres in 1933 to 1,882 acres in 1935. The price of cotton showed some recovery from 1933 onwards and by 1938 planters were cultivating over 1,000 acres, while the share-croppers cultivation declined to 1,500 acres.

This historical outline reveals the share-cropping system of Montserrat as a desperate expedient to which planters resort as a means of retaining the

ownership of their estates and securing an income in periods of depression. Share-cropping is not a system of land tenure, but is only a method of paying wages in kind in *lieu* of cash. It does not provide, nor is it intended to provide, a sound basis for the development of peasant agriculture, and the landowner always regards his role of "landlord" as a temporary one.

The Present System The area of land allotted to the share-cropper is usually either ½ or ¾ of an acre for a woman, and ¾ or 1 acre for a man. Many share-croppers take up two or more plots, usually on separate properties, in their desire to secure abundant occupation. The share-cropper has no security of tenure, and although he may cultivate the same plot of land for ten years in succession he does so only on a year to year basis. He is not encouraged to establish his home on the holding. Some landlords refuse to allow a share-cropper to cultivate the same plot of land for more than three or four years in order that a leguminous crop—usually Bengal bean but occasionally pigeon pea—may be planted. The share-cropper benefits from the improvement in soil fertility but the move from plot to plot emphasises the transitory nature of his occupation, prevents him from identifying his welfare with that of any particular plot of land, and encourages him to regard the maintenance of fertility as a matter for which he has no responsibility. The most frequent cause of transfer is, indeed, the unwillingness of the share-cropper to continue the cultivation of land the fertility of which he has lowered by his improvident method of cultivation.

Cotton is, for all practical purposes, the only crop the share-croppers have been permitted, or have desired, to plant, and this enables the landowner to resume the cultivation immediately he can attract labourers with the offer of wage payments. The share-cropper is naturally unwilling to incur expenditure when the residual benefit may accrue to the landowner, and many plots of land have been cultivated year after year in cotton without the application of any kind of manure. Many landowners have become alarmed by the declining productivity of their land, and, in recent years, a few have offered their share-croppers loans for the purchase of artificial fertilisers or have delivered cattle droppings to points in close proximity to the plots, but these practices have not yet become sufficiently widespread to arrest generally the decline in soil fertility.

Soil Erosion The most important and urgent agricultural problem in Montserrat is the prevention of soil erosion. It would be erroneous to attribute soil erosion wholly, or even mainly, to share-cropping, for the change from sugar-cane to cotton has undoubtedly been the primary factor. Cotton is very sensitive to weed competition and the soil is kept clean weeded during periods when heavy rains are experienced. The crop is grown on banks constructed more or less along the contours, which are effective in varying degree in reducing the surface run-off of water to non-erodible velocities, though breaches in them sometimes occur during exceptionally heavy and prolonged rains. But it is the hoe which is the main cause of erosion, for the soil is invariably dragged down the slope during the annual construction of new banks.* Boulders near the upper boundary of a plot eventually become exposed, while those near the lower boundary become buried in transported soil.† The division between plots becomes clearly marked in the course of time by a small escarpment, and the ultimate effect will be the construction of wide terraces with excessively large vertical intervals.

Neither landowner nor share-cropper has recognised in any practical form the responsibility which each owes to the other, and which both owe to the community, in respect of soil conservation. The construction of anti-erosion structures, as distinguished from their maintenance, is clearly the responsibility of the landowner and not of the share-cropper, for such structures must be planned in relation to a topographical unit which almost invariably will embrace the plots of many share-croppers. Moreover, the individual share-cropper is not likely to possess, and cannot be expected to acquire, the knowledge and skill, and the simple equipment, necessary for the planning and construction of such structures. Finally, it would be unreasonable to expect, or to require, the share-cropper to invest capital, no matter how small the amount of effort and money involved, from which he may not derive full benefit and for which he may not receive compensation; in these respects the share-cropping system hinders the adoption of sound agricultural practices.

There is some doubt as to whether lack of capital or lack of knowledge is the more important cause of the apparent indifference of landowners to soil erosion.‡ Certainly some anti-erosion structure, such as vegetative barriers, are not expensive either to establish or to maintain. The Agricultural Department has been alive to the gravity of the problem, but the resources which Government was able to place at its disposal for investigational purposes were far from commensurate with the magnitude and urgency of the task.

The Share The share-cropper in Montserrat usually receives a "half-share", but where the soil is poor, and where the cropper has to clear the land, he may receive a "two-thirds share". In the case of Montserrat it is not wholly clear what the share-cropper and the landowner share. The share-cropper is entirely responsible for preparing the land and for planting, cultivating and harvesting the cotton. The share-cropper delivers the seed cotton to the estate yard in a reasonably clean condition (i.e. free from excessive foreign matter, leaves, etc.). The seed

*The word 'hoerosion' has been coined as an apt description of this form of erosion.

† In Nevis the soil is said to 'grow stones'.

‡ Considerable progress has been made in the Leeward and Windward Islands (and also in Jamaica) during the past years in the adoption of anti-erosion measures.

cotton is then weighed in the presence of the share-cropper and a deduction is made to cover the loss in drying. The deduction is normally 10% of the gross weight but may be as much as 15% on wet days. The share-cropper is then recorded as having delivered 50% of the net weight of the seed cotton; the landlord takes over the entire seed cotton, including the cropper's share, at this stage, and arranges for it to be sun-dried, cleaned, sorted, ginned, baled and marketed. The cost of these operations, except ginning, is deducted from the proceeds of the lint, and the share-cropper is paid one-quarter of the net proceeds per pound of lint for each pound of seed cotton with which he is credited in the landowner's books. The landowner retains the seed, the proceeds of which are considered to compensate for the expenses of ginning. Thus, the landowners may be regarded as the agent of the share-cropper for the processing and marketing of the share-cropper's cotton.

Two details of these transactions were the frequent subject of complaint by share-croppers. First, the deduction for moisture is alleged to be excessive, and, second, the share-croppers claim that the price of seed-cotton should be more than one-quarter the price of lint. Losses in weight on drying vary on the same estate from day to day and from year to year, and vary from estate to estate. Schouten shows that whereas deductions of 10% or more may be reasonable on estates in wet districts, they are excessive, and in some cases grossly so, for estates in dry districts (17). There is no simple means, however, by which the correct deduction can be ascertained. The assessment of seed cotton at one-quarter the price of lint appears to have been reasonable when it was first introduced, for the records of three estates over the period 1909—13 show that the recovery of lint from seed cotton average 24.2 %. But this rate is no longer reasonable, for the selection of a superior strain has improved the out-turn of lint, and the average recovery for five estates from 1934 to 1938 was 30.8%. The grounds for these two complaints could be removed by the simple expedient of adopting the practice current in Nevis where the seed cotton is divided into two equal parts and the share-cropper is entitled to remove his share. Some share-croppers in Nevis sell their seed cotton to the owner of the land on which it was grown but a larger proportion is marketed through the Government Cotton Ginnery.*

Returns to Landowner Share-croppers in Montserrat are practically unanimous in complaining that the landowners obtain an excessive remuneration. Now, the income of the landowner is subject to violent fluctuations, the characteristic feature of the system being that both parties, landowner and share-cropper, prosper or suffer together. The cotton plant is very sensitive to variations from the ideal rainfall, and there are wide fluctuations in yield from year to year. Estates differ in their variability in yield but it is by no means uncommon for the yield in one year to be either double or half that of the preceding year. There is an even wider range between the yields of share-croppers on the same estate, some obtaining less than 200 lbs. of seed cotton an acre, and others more than 1,000 lbs. The price of lint, too, has exhibited substantial change, being, for example, nearly twice as much in 1939/40 as in 1932/3. The average gross return per acre of cotton for the island as a whole has ranged in recent years from £6 in 1931/2 to £22 in 1938/9.

Many landowners allow share-croppers free pasturage, and plots of less accessible land for the cultivation of ground provisions, either gratis or on a nominal share basis. Share-croppers are generally permitted to cultivate the steep sides of ghauts (ravines) without payment of rent. Some landowners make occasional gifts of organic manure to their share-croppers, or grow a crop of green manure on the plot. These, however, are perquisites and not a recognised obligation of the landowner, and the practice of providing free pasturage, provision grounds and manures varies widely between estates and from time to time on the same estate.

Schouten calculated that the average annual net return per acre to the landowners of 9 estates during 1934/8 was nearly £4. 10s. which is considerably in excess of the £1. 10s. or £2 per acre charged for cash rental (17). It may be noted that the gross returns per acre on these 9 estates was above (about 15%) the island average but there can be little doubt that when good yields and high prices are obtained the landowner's share greatly exceeds the equivalent cash rent. On the other hand, when low yields and low prices occur together the share may be less than a reasonable cash rent.

Now although the great majority of the share-croppers dislike the system they prefer it to working for wages on an estate. The fact is that most of the work on a cotton estate can be, and usually is, performed by women and children.* The principle demand for male labourers on cotton estates in Montserrat occurs in November and December for the preparation of the land, and thereafter there is little employment except for a few permanent hands. Provided the share-cropper has an adequate area of land—and many of them have plots on several estates—he can determine for himself the amount of gainful employment he will undertake.

Nevis

The share-cropping system of Nevis differs in detail from that of Montserrat, but is equally unsatisfactory as a foundation for peasant agriculture (15). The principal difference in detail has already been referred to. It is that the share-cropper markets his own share of the seed cotton in Nevis, whereas the landowner acts as marketing agent for the share-cropper in Montserrat.

* There is no Government Cotton Ginnery in Montserrat.

* e.g. on 3 cotton estates during 1937 the total wages paid to women were two and a half times those paid to men.

Soil erosion is much less serious in Nevis than in Montserrat or St. Vincent, because the land is generally less steep, the soils are relatively non-erodible, sugar-cane is more widely grown, cotton is restricted to a belt of low rainfall and much land is under grass. It is of interest to note that some sugar planters recognised soil erosion as a grave problem long before this subject became fashionable in agricultural literature, for a few estates have an extensive system of stone wall terraces which were probably constructed during the days of slavery. Soil fertility, however, has been reduced to low level by relentless and improvident farming, for which the share system is partly responsible. Some of the more progressive landlords, who have become alarmed by the declining productivity of their estates, have offered their share-croppers special facilities for obtaining animal manure in recent years. For example, some share-croppers are permitted to collect sheep, or cattle droppings, from the estate grazing grounds, free of cost or at a nominal price. Some landlords cart manure and deposit it near the share-croppers' holdings either without charge or at a cheap rate. Manuring is not, however, practiced generally, the dressings are rarely adequate, and the practice does not form a recognised part of the share-cropping system.

The possibility of a restoration of plantation agriculture appears more remote in Nevis, where only one estate, which is devoted to coconuts, has a pay-roll of consequence, than in Montserrat, and the landowners of Nevis might be more willing, in consequence, to accept permanently the role of landlord. In such circumstances there would be no difficulty in devising a satisfactory system of share tenancy—as contrasted with share-cropping—but for the fact that the financial stress which prevents landowners from being planters also precludes them from becoming satisfactory landlords.

The share tenancy system is firmly established and growing in popularity in the wheat and corn belts of Canada and the United States of America. There its success is mainly due to the presence of monied individuals who are able and willing to invest in farm land and equipment but lack the time or inclination to farm themselves, and of other individuals desirous of farming but inadequately endowed with capital. The English cash tenancy system similarly owed its growth to the existence of landed gentry who were willing to invest in capital equipment and improvements, and its recent decline was due to their increasing financial stress. The landowners of Nevis and Montserrat lack that capital which made successful the share and cash tenancy systems of Canada, the United States of America and the United Kingdom.

Cash Tenancy

Comprehensive data regarding the number of cash tenants and the area of land they occupy in the Leeward and Windward Islands are not available, but the land so occupied falls into two broad categories : (i) the outlying portions of some estates, other parts of which are cultivated by planters and/or share-croppers, and (ii) entire estates.

Land in category (i) is usually that which has never been cultivated with wage-paid labour, because of either its inaccessibility, its steepness, its low fertility or the climate. Inaccessibility is probably the most prevalent defect of such land and this renders it unsuitable for share-cropping because the supervision of the harvesting would entail excessive cost. Tenants of such land are usually permitted to choose their own crops and method of cultivation; but they generally plant hardy food crops requiring only intermittent attention. Rentals are usually low and sometimes merely nominal, for the tenancy is regarded more often as a reward to a worthy share-cropper or labourer than as a distinct commercial proposition. When the cash tenant is also a share-cropper, the cash rent is generally treated as an advance recoverable from the proceeds of the share-cropped land. Tenancy is normally on a year to year basis and neither tenant nor landlord is usually seriously concerned with the prevention of soil erosion and the maintenance of soil fertility, the tenant because he lacks security of tenure and the landlord because rents are not an important source of revenue.

Some estates (ii) have been rented out in their entirety in small holdings. The landlords differ in their origin and include retired planters, inheritors of estates and investors, but they share the common characteristic of preferring to be landlords rather than planters. Most of these properties are inferior in respect of soil and climate to the surviving plantations. The landlords generally require their tenants—and the tenants, it may be noted are only too willing—to concentrate on the production of a single cash crop. The landlord acts as agent for the sale of his tenants' produce. In Antigua, for example, the factory pays the proceeds of the sugar-cane to the landlord for distribution among his tenants. The factory recognised the advantage of obtaining large and regular deliveries from a single supplier—instead of dealing individually with numerous small growers—by paying a higher price (about 1/- per ton more) for such cane. The collection of rent by the landlord is facilitated by his handling of the crop proceeds.

Cash tenancy is usually on a year to year basis and written leases are rare. A tenant given notice to quit is permitted to remain in occupation until he has reaped any annual crop already planted, and, in the case of sugar-cane, to reap the first ratoon or to receive compensation for its value. The tenant who pays his rent regularly and promptly is unlikely to be disturbed, but in the absence of the security of tenure conferred by a long term lease he is equally unlikely to make any long term investment on the holding or to concern himself greatly with the maintenance of its fertility. Cash tenants do not as a rule live on these holdings, partly because they lack security of tenure and partly because they prefer the simple amenities of a village.

The fact that these landowners are landlords by choice or resignation and do not desire to become planters offers a prospect of establishing peasant farming on a more satisfactory basis. The essential reforms are similar to those suggested for Government land settlements, but it may be stated at once that these reforms will necessitate capital expenditure on a large scale and will depend for their success on a radical change in the outlook of both landlord and tenant. Dwellings, farm buildings, water for man and beast, and, where necessary, roads, traces, and anti-erosion structures will involve heavy expenditure; and it remains to be seen whether landlords will be able and willing to furnish this capital and what share, if any, the tenant should assume. Government land settlements may point the way to a sound system of peasant agriculture, and legislation* may protect both tenant and landlord from abuses, but neither can ensure success in the absence of mutual respect and a desire to co-operate.

Squatting

Squatters are said to be numerous in Dominica and St. Lucia but comprehensive data regarding their number and the amount of land they have occupied are not available. In both these islands there is doubt as to the boundaries of some of the alienated land. In the other Windward Islands and in the Leeward Islands, taxes are levied on land, and, as the Crown can resume land on which taxes are not paid, it is a comparatively simple matter to distinguish *bona fide* occupiers. There is no land tax in either Dominica or St. Lucia and, since even *bona fide* owners may lack valid titles, the elimination of squatters would be a complicated process. Breen recognised the difficulties as long ago as 1844 when he mentioned the disposal of Crown or waste land in St. Lucia as a "preliminary question it would be politic to set at rest" and he doubted whether "a general survey of the Crown lands..... could be accomplished without considerable expense" (1). This preliminary question still remains largely unanswered.

Squatters usually resort to the mountains where they fell forest and indulge in a ruthless exploitation of the soil until yields fall to a level which prompts them to clear more forest. They rarely construct more than a rude and temporary shelter on the land, because they have no intention of taking up permanent residence. Much of the land on which squatters have practised shifting cultivation is especially liable to erosion, and they are said to have degraded extensive areas of land.

The fact that many individuals in Dominica and St. Lucia are squatters indicates that they desire, or at least feel themselves compelled, to derive their livelihood from the land, and this suggests that the difficulties of acquiring land in a legitimate manner are so great that they find it necessary to pursue furtive methods. It is important, not so much to suppress squatting as to ensure that cultivation is carried on without detriment to the community, and the solution may lie in evolving a permanent system of agriculture more conducive to the well-being of the individual than squatting, and in making suitable land readily available at moderate rentals and with security of tenure. Once the squatter can be persuaded to establish a permanent home on the land he cultivates, and to regard the maintenance of soil fertility as a matter of vital personal interest, the most undesirable features of squatting will be removed.

It is unfortunate that many squatters, in their desire to avoid interference, have resorted to relatively inaccesible land which should have remained under protective forest. It is in the public interest that such land should be resumed by Government and restored to forest, but such a procedure might result in a recrudescence of squatting elsewhere unless opportunities are afforded the squatters for gaining a lawful livelihood.

Freehold Tenure

It has been shown that the Act of Emancipation conferred on the bulk of the population of the British West Indies for the first time the civil right to acquire land, but that both the British and local Governments discouraged the development of peasant agriculture by placing restrictions on the acquisition of Crown lands with the object of ensuring an adequate supply of wage-earning labourers for the sugar estates. Nevertheless, some planters were forced into bankruptcy during the recurrent crises to which the British West Indian sugar industry was subjected during the nineteenth century, and a few estates were offered for sale in small-holdings. Labourers, however, had few opportunities for acquiring capital, and the competition for land was so keen that few could acquire a holding of a size sufficient for the maintenance of themselves and their families, and the majority found it necessary to combine wage-earning with agriculture. Emigration afforded opportunities to many individuals to accumulate savings for the purchase of land.

Leeward Islands There were marked differences between the various islands in the amount of land which came on the market. In Antigua and St. Kitts practically all the cultivable land had long been alienated, labour was abundant and cheap, and most planters managed to struggle on in sugar.* Nevis, too, remained for a long time predominantly a sugar island although the planters succeeded in maintaining the ownership of their estates only by resorting to the share-cropping system. There was no unalienated land in Montserrat, and first the sugar planters, and later the cotton planters, adopted share-cropping in preference to selling their estates in small-holdings.

* The Leeward Islands Small Holdings Act of 1938 provides a suitable framework for peasant agriculture but few landlords or tenants appeared familiar with its details at the time of this survey.

* The area of cultivable Crown Land in 1896 was estimated at 150 acres in St. Kitts and 50 acres in Nevis. See (2).

Windward Islands Dominica and St. Lucia differed from the Leeward Islands in that they contained large areas of Crown Land,* and it was therefore possible to make provision for small-holders without dispossessing planters. But in neither island was it always possible to distinguish between alienated and unalienated land. Crown lands were offered for sale in St. Lucia in 1890, but the conditions were unattractive, for the land was sold indiscriminately in small lots, most of which were inaccessible by road. The applicant was required to pay a deposit and to complete the purchase in four equal annual instalments. The purchase of such land offered nothing which the squatter could not obtain without cost.

Most of the cultivable land in St. Vincent had passed into the hands of planters, a few of whom controlled a large percentage of the total area. The position of the agricultural labourer had become desperate by about 1890, for the planters were unable to cultivate all their land and were unwilling to rent or sell. St. Vincent then contained about 25,000 acres of Crown Lands and from 1890 to 1896 portions were offered for sale in small lots; but the scheme proved a failure because the land in question was situated in the centre of the island, at a considerable elevation, remote from markets and sources of employment, and was unprovided with roads. Much of the land consisted of steep slopes, difficult to cultivate and liable to suffer from heavy rains and floods. In 1896 many of these holdings were damaged by floods and much of the cultivation was swept away.

Grenada was the only island in the Leeward and Windward groups where labourers were afforded widespread opportunities for acquiring small-holdings. These facilities were the indirect result of the collapse of the sugar industry and the substitution of the cacao industry. Cacao had been grown in Grenada on a small scale for many years, but up to the 1850's planting had been confined to the higher lands, between 600 and 800 feet above sea level, because it was believed that cacao would not grow satisfactorily at lower altitudes. Small scale trials disproved this belief, and, during the recurrent depressions in the sugar industry, increasing numbers of estates were converted to cacao. A field of cacao seedlings gives practically no yield during the first five years and does not attain full production until 15 to 25 years after planting. The impoverished sugar planters were unable to finance the establishment of cacao fields with wage paid labour and they therefore adopted the 'garden' or 'contract' system whereby the 'contractor'—usually a labourer—agreed to bring a certain area of land —normally 1 to 3 acres—into bearing cacao.† The contractor was entitled to plant provisions and to consume or sell any produce derived from the land. He worked for wages on the estates or elsewhere when opportunity offered or necessity demanded, and he could obtain occasional small cash advances from the planter. When the estate owner took over the contract—usually at the end of five years—he paid the contractor at an agreed rate for every cacao tree. The planter experienced no difficulty in raising loans on the security of the bearing cacao, for the period 1870 to 1920 was a 'golden age' for the cacao industry and 'cacao mortgages' were regarded as gilt-edged securities bearing a high rate of interest.

The contractor received —a substantial lump sum at the termination of his contract with which he could purchase land on bankrupt sugar estates, or on the upper portions of those estates which were being converted from sugar to cacao. Such land was available in Grenada in substantial areas during and after the 1870's and was sold on instalment systems at rates ranging from £20 to £50 per acre near the coast, and from £4 to £6 per acre in the forested mountains. Thus it came about that by 1896 Grenada was the only island in the Leeward and Windward Groups in which any substantial body of peasant proprietors had become established. Up to this date the various Governments had done little or nothing to encourage peasant agriculture.

Land Settlement The West India Royal Commission of 1897 recommend that the respective Governments should take the lead in settling the labouring population on the land as small peasant proprietors, and that, where necessary, Governments should not hesitate to assume powers of compulsory acquisition of land. The labouring population in St. Vincent was considered by the Commission to be especially in need of assistance; for they could obtain neither adequate employment nor land to cultivate. The Government of St. Vincent embarked almost immediately (1899) on an extensive land settlement scheme and Carriacou followed in 1903; but other Governments were slow to follow these examples and it was not until 1916 that Antigua became the first of the Leeward Islands to inaugurate a Government land settlement. Further Government Land Settlements were commenced during the 1930's on the strong recommendation of the West Indian Sugar Commission of 1929/30.

There were many more peasant proprietors in the Leeward and Windward Islands in 1939 than in 1896, the increase being attributable in large measure, both directly and indirectly, to the activity of the respective Governments. Data concerning smallholdings are not available for St. Kitts; but it is probable that there are still many more peasant proprietors in Grenada than in all the other islands combined. The increase in the number of small holdings in St. Vincent between 1896 and 1938 is especially noteworthy, and it is probable that, excluding Grenada, St. Vincent contains as many peasant proprietors as all the other islands combined. Thus, peasant proprietors are concentrated largely in the two islands of Grenada and St. Vincent.

* As late as 1896 it was estimated that Dominica contained 80,000 acres, and St. Lucia 50,000 acres, of cultivable Crown Lands, but both estimates must be considered gross exaggerations.

† For details of the contract system in Grenada, see (3), and for Trinidad see (16).

The majority of those planters who sold the whole or part of their estates in small holdings did so presumably because the prospects of earning profits with wage paid labour were considered remote. The Government of St. Vincent exercised powers of compulsory acquisition, but the estates selected for land settlement were ones which had "practically ceased to be cultivated" (2). Certain other Governments were content to utilise Crown Lands or land which had been acquired for other purposes. Consequently, much of the land now in the hands of peasant proprietors is handicapped by low fertility, steep slopes or inaccessibility.

Few agricultural labourers were able to purchase land, for low wage-rates, combined with seasonal and intermittent employment, prevented them from saving the substantial sums of money required, and most of the purchasers were the more successful artisans, enterprising individuals who had worked and saved abroad, or, in Grenada, cacao contractors. Few such persons could afford to acquire a holding large enough to provide full-time occupation for themselves and their families, but some already had, or subsequently acquired, additional land and now control two or more plots separated in some instances, by considerable distances. Many peasants found it necessary to supplement their savings with loans, and these loans, if substantial in amount, were usually obtainable only from produce dealers to whom the borrower was required to sell his crops. Most peasants exhaust their savings and credit in purchasing the land and few command sufficient additional capital for the full and effective development of their holdings. Many peasants are compelled to supplement the income from their holdings with wage employment, and to many of them agriculture is not so much a mode of living as a supplementary source of income. Indeed, the one great advantage common to all the forms of land tenure that have been discussed is that the holding serves as a reservoir of employment; and this is especially important in islands whose welfare is founded on a single export crop, the labour demands of which vary from year to year and seasonally during each year.

West Indian peasants regard freehold as the only secure form of land tenure. There is a keen desire among many classes in the West Indies to own a piece of land for the prestige and the security which it offers. The desire of West Indians to identify their welfare with that of the land is an objective worthy of encouragement; but although West Indian experience has justified the peasant in regarding freehold tenure as the only secure form of tenure, experience elsewhere has demonstrated that other forms of tenure not only afford the worthy tenant security but also eliminate those disadvantages to both the peasant and the community which have become associated with the unrestricted freehold tenure of land in the Leeward and Windward Islands.

Disadvantages of Freehold The disadvantages of freehold to the peasant in the Leeward and Windward Islands are several. Most of the land which has become available for purchase in small holdings is characterised by some such defect as low fertility, inaccessibility, or steep slopes; in many instances these handicaps, either singly or in combination, preclude the peasant from attaining a reasonable standard of living. The competition for small-holdings is such that high prices can be charged, and the command of capital is the basis on which purchasers are selected. The man with capital can obtain land even if he has no ability as a farmer, whereas the man with ability but no wealth is debarred. Several consequences emerge from the high cost of land. The plot of land which most individuals can afford to purchase is too small to afford full-time occupation for the purchaser and his family. His capital resources are exhausted by purchase and he often lacks sufficient credit to develop his holding fully, and especially to provide the capital improvements essential to the maintenance of fertility. When, at a later date, he is able to purchase or rent additional land, it is usually some distance from the original plot. Much time and energy is wasted in proceeding from the home to the various plots, praedial thieves are encouraged, and the cultivator cannot give that constant attention to the various plots which intensive cultivation involves. With individuals cultivating separated plots of land it is extremely difficult to develop a community sense. Mixed farming cannot be practised when the plots are separated, for farmyard manure is bulky and transportation is a handicap.

The drawbacks of freehold tenure to the community are not less important. The security from interference may degenerate into licence. Much of the land in peasant ownership has been degraded by improvident farming. In some cases lack of capital has been responsible, the proprietor being compelled by stress of economic circumstances to concentrate on immediate gains at the expense of the future. In other cases, lack of knowledge has been the occasion of soil degradation. The population directly dependent on the land in the Leeward and Windward Islands is increasing at a rapid rate and it is imperative that further wastage of soil capital should be prevented. The question of whether soil degradation has been due to unwillingness, inability or ignorance is relatively unimportant. It is important that the peasant should be denied the opportunity to abuse the land; and this implies some form of tenure other than unrestricted freehold. Anti-erosion measures must be planned in relation to a topographical unit and the individual peasant proprietor is powerless to undertake effective measures except in concert with his colleagues. The possibility of persuading numerous independent freeholders to act in unison, or of their acting on their own initiative, is so remote as to warrant no serious consideration. It is essential in the writer's opinion, that whole topographical units should be under the control of a single landlord who would

be responsible for the construction and maintenance of those structures which affect the efficiency of more than one holding. The question of whether the work should be performed by the individual tenant, in so far as his own holding is concerned, is a matter of detail, the important thing being that the responsibility should rest with an authority exercising control over the whole area.

The heavy demand for land and the high prices which can be realised for small holdings have provided scope for speculators whose sole interest lies in the unearned increment they can gain.

All the land settlements in the Leeward and Windward Islands which had been sponsored by Governments up to the time of the present survey provided for the ultimate acquisition of freehold rights by the allottee. There was one important difference however, between certain settlements, notably the pioneer ones in St. Vincent, and the acquisition of land from private owners that occurred elsewhere. The difference lay in the fact that the Government of St. Vincent exercised control over the allottee until he had completed the purchase of the land. Officers were appointed by Government for the special purpose of administering the Land Settlement Ordinance; and both contemporary records and the testimony of the older settlers bear witness that their duties were performed with skill and understanding. It would appear, however, that Government assistance and even interest, ceased abruptly when the settlers completed the purchase of the land.

Allottees on the older settlements long ago completed the purchase of their lots; and the older setttlements thus now provide information regarding the merits and demerits of the freehold system. It seems clear that, apart from some unforseeable event, such as occurred during the conversion of sugar to cacao in Grenada, the extension of peasant agriculture in the Leeward and Windward Islands will depend primarily on Government action, and a close examination of these settlements is therefore of importance.

The remainder of this report is devoted to a detailed examination of peasant families associated with certain land settlements, which have been selected as typical of the various phases of enthusiasm in the respective islands of Nevis, Antigua and St. Vincent.

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RESEARCH AT THE INSTITUTE OF TROPICAL AGRICULTURE, PUERTO RICO

The primary function of the Institute of Tropical Agriculture in Puerto Rico is the conduct of investigations on the more fundamental problems which confront agriculture in the tropics. The studies embrace plant physiology, cytogenetics, botany and horticulture generally, and economic geography. Under the first head, emphasis is laid on the functions of hormones, and a detailed study was made of the action of such substances as naphthaleneacetic acid (NA) and 2, 4—dichlorophenoxyacetic acid (2, 4—D) incontrolling the fruiting and formation of "slips" in the pineapple. Preliminary investigations into the physiological reactions involved in the stimulation of root development by auxins such as indolebutyric acid, using *Hibiscus* cuttings, showed an increase in soluble nitrogen at the base of the cutting due to proteolysis in the leaf where a reduction in the amount of insoluble nitrogen takes place.

An extended study of the use of 2, 4—D as a selective herbicide has a practical bearing, particularly in the case of the sugar cane, on which there is no

toxic effect. It is of use, therefore, for the control of weeds. Owing to differential susceptibility, it is desirable, in practice, to know the reaction of the particular weed which it is desired to control. Four groups are recognized, highly susceptible, controlled by concentrations of 0.05 per cent., less susceptible requiring concentrations of 0.15 per cent., moderately resistant controlled by concentrations of 0.2 to 0.3 per cent., and resistant, incapable of control. Most of the weeds in Puerto Rican cane fields are stated to fall in group 1 and can be eradicated at a cost of 30 cents per acre for chemicals.

With such a range of susceptibility in different organisms, the question naturally arises whether the microflora of the soil may not be thrown out of balance. If increased growth results from the removal of competition from weeds, the reverse may be the case if the complex interaction of the organisms in the soil is disturbed. Pot experiments with fluorescein in concentrations rising to 5 parts per million gave negative results, but it is unlikely that these covered more than the microflora, bacteria and fungi, and included the larger but very important soil fauna, particularly worms.

Cytological investigations led to the determination of the chromosome number of some of the more important grasses. The question of the nature of the incompatibility which leads to failure to set seed when certain sugar cane crosses are made, was investigated. Incompatibility may result from failure to effect chromosomal fusion, or from incompatibility between embryo and maternal tissue. Attempts to determine this point gave negative results since, from the three highly sterile crosses made, Co 201 X PR 900, Uba X R 900 and M 28 X M 317, only one nearly mature embryo of the last cross was obtained, though the indication is that the failure occurred before or at fertilization. It was, however, found possible to cultivate *in vitro* embryos of the fertile cross POJ 2878 X *S. spontaneum* when they had reached the length of 66 microns.

Some interesting studies are reported on the differentiation of leaves and roots in answer to the question as to why two cells, presumbaly having the same genetical composition, give rise to such different structures. This work was conducted with a species of *Taraxacum*, sections of the roots of which, if even only a few millimetres in thickness, can form new plants. Normally such sections up to several centimetres in length form a callus at the distal end from which root may develop, while, from the callus developed at the proximal end, leaves arise. There appears to take place a re-distribution of materials in which auxins play an important part. Treatment of the distal end with indolebutyric acid, 10-200 p.p.m., leads to abundant root development at this surface; when the treatment is applied to the proximal end, the position is more complicated. Here moderate concentrations (10-50 p.p.m.) inhibit leaf formation and may result in the formation of a few small roots; higher concentrations (100-400 p.p.m.) lead to the production of abundant roots from the proximal surface.

(Review of 4th Annual Report of the Institute by H.M. Leake published in *International Sugar Journal* 49 : 144, 1947)

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Deterioration of Cane in Storage Pile

The deleterious factors that affect the purity of the juice of cane stored in a stock pile at the factory are many in number. A study of those that follow has been made in Hawaii. *Length of time in the pile* : without much doubt this is the No. 1 factor. Experience shows that there is not much effect on the juices during the first 24 hours. *Moisture content —Wet or dry* : most of the inversion and consequent deterioration of the juice purities is due to bacterial activity ; moisture which dilutes the juice will promote and accelerate this activity. *Original condition of cane* : the more the cane has been crushed and mutilated during the rough harvesting methods now used in Hawaii (where mechanical harvesting by rake, grab, and bulldozer is prevalent. —Ed.), the faster the purity will drop when the cane is put into the pile. The amount of dead cane, half-sour stalks and immature cane also contributes to this effect. *Size of pile* : experience shows that a large pile deteriorates faster than a small one, due to the increased pressure and higher temperature rise. *Amount of extraneous matters* : poorly burned cane, green tops, damp trash and dirt are highly undesirable, but little can be done about it except to keep the pile small and the time of storage short. *Length of time between burning and piling* : this is a time factor which is of great influence on juice deterioration. *Temperature and humidity* : a few degrees rise in temperature and a warm, humid condition in the pile have a marked stimulating effect on bacteria and consequently on juice deterioration. As an example, a pile of 100 tons of cane was set aside and 25 tons of this cane was ground each day for four consecutive days. This cane was from a good burn, had been harvested about 24 hours when piled, and was fairly free from dirt and trash. The figure for Brix, pol., and purity on the first day were 15.70, 13.86 and 883, respectively. After the first day pol. and purity steadily dropped and on the fourth day were 12.93 and 83.6. This is by no means an extreme case, but it emphasizes the fact that storing cane in piles for more than 24 hours is expensive. (*Sugar*, 41, 49-50, 1946).

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